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PENNSYLVANIA
GEOLOGICAL SURVEY
FOURTH SERIES

TOPOGRAPHIC AND GEOLOGIC

ATLAS

of

PENNSYLVANIA

No. 96

TYRONE QUADRANGLE

GEOLOGY AND MINERAL RESOURCES

By

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(Prepared in cooperation between the United States Geological Survey and the Pennsylvania Topographic and Geologic Survey)

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TOPOGRAPHIC AND GEOLOGIC SURVEY
GEORGE H. ASHLEY, *State Geologist*
Harrisburg, Pa.
1939

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CONTENTS

	Page
Introduction	1
Location	1
General relations	1
Appalachian Highlands	2
History of the Appalachian Highlands	3
Topography	5
Relief	5
Drainage	6
Descriptive geology	7
Stratigraphy	7
Cambrian system	7
Pleasant Hill limestone	8
Warrior limestone	9
Hiatus	10
Gatesburg formation	10
Mines dolomite	12
Larke dolomite	13
Ordovician system	13
Stonehenge limestone	14
Nittany dolomite	15
Axemann limestone	16
Bellefonte dolomite	17
Chazy group	18
Carlim limestone	18
Unconformity	20
Lowville limestone	22
Rodman limestone	23
Unconformity	23
Trenton limestone	25
Reedsville shale	25
Oswego sandstone	26
Juniata formation	28
Silurian system, by Frank M. Swartz	29
Tuscarora sandstone	30
Clinton group	33
Castanea sandstone	33
Rose Hill shale	34
Keefer sandstone	38
Rochester shale	39
McKenzie formation	41
Bloomsburg red beds	46
Wills Creek shale	47
Tonoloway limestone	48
Keyser limestone	51
References	56
Devonian system, by Bradford Willard	57
Helderberg group	57
Oriskany group	59
Shriver formation	59
Ridgeley formation	60
Onondaga group	62
Hamilton group	63
Marcellus formation	64
Mahantango formation	64
Portage group	65
Tully limestone	66
Burket shale	66
Harrell shale	66
Brallier shale	67
Chemung group	68
Catskill continental facies	70

Page

References 72
Carboniferous system 73
Mississippian series 73
Pocono formation 73
Burgoon sandstone member 73
Quaternary system 74
Terrace gravels 74
Alluvium 74
Structures 75
Sinking Valley anticline 75
Scotch Valley 77
Birmingham fault 77
Minor faults 78
Geologic history 79
Proterozoic era 79
Paleozoic era 79
Cambrian period 79
Ordovician period 80
Silurian period 82
Devonian period 83
Carboniferous period 85
Mesozoic and Cenozoic eras 86
The Appalachian uplift 86
Cycles of erosion 86
Glacial epoch 88
Recent epoch 88
Progress of life 88
Mineral resources 89
Iron ore 89
Lead and zinc 90
History of mining operations 90
Occurrence and character of ore 91
Production 92
Future prospects 92
Barite 92
Building stone 92
Ganister 93
Federal Refractories Company 94
E. R. Baldridge Company 95
Harbison-Walker Refractories Company 95
Brick clay, sand and gravel 96
Limestone 96
Ordovician limestones 97
Helderberg limestones 103
Crushed stone 105
White clays 105
Introduction 105
Residual clays from Mines dolomite 106
Quality of the Mines and Gatesburg clays 106
Distribution and development 107
Furnace Road, Dungarvin, Patton, Pennington, Schoenberger pits..107-108
Residual clays from Oriskany sandstone 108
Alexandria Fire Clay Company 108
Petersburg 109
Caves 109
Water resources, by S. W. Lohman 110
Soils 111

ILLUSTRATIONS

Page

Plate 1. Geologic map of the Tyrone quadrangle ..... In pocket
2. Geologic structure section in the Tyrone quadrangle ..... In pocket
3. Columnar geologic section in the Tyrone quadrangle ..... In pocket
4. A. The Allegheny Front northwest from Tyrone; B. Foothills of the Allegheny Front; C. Alexandria Valley and Tussey Mountain from southeast ..... opposite 10
5. Gatesburg formation near Shoenberger 11
6. Limestone quarry on Elk Run 19
7. A. Lemont limestone member of the Carlim limestone; B. Lowville, Rodman and Lemont limestones at Union Furnace 21
8. A. Vertical wall of Rodman limestone on Elk Run; B. Trenton limestone at Union Furnace 24
9. A. Reedsville shale near Tyrone; B. Tussey Mountain and slide rock near Goodman 27
10. Thrust fault on Pennsylvania Railroad ½ mile northeast of Barree 32
11. A. Boulder of Tuscarora quartzite with *Deadalus archimedes;* B. Sequence of Helderberg (New Scotland) limestone and Shriver sandstone near Tyrone 37
12. A. McKenzie limestone, Rochester shale, and Keefer sandstone exposed in railroad cut southeast of Barree; B. Panorama with A. ..... opposite 40
13. A. Shriver sandstone near Tyrone; B. Ridgeley sandstone; panorama with A. 61
14. Birmingham overthrust fault 76

Figure 1. Index map showing the location of the Tyrone quadrangle..... 1
2. Physiographic divisions of Pennsylvania 2
3. Chart showing Silurian formations in Maryland, Pennsylvania, and New York ..... opposite 32
4. Cross section of structure at Birmingham 78

Description of the Tyrone Quadrangle, Pennsylvania

By Charles Butts

INTRODUCTION

Location.—The Tyrone quadrangle is located in central Pennsylvania and includes parts of Blair, Centre and Huntingdon Counties. It is bounded by the parallels of 40° 30′ and 40° 45′, and by the meridians of 78° and 78° 15′, comprising thus one-sixteenth of a square degree, which in this latitude has an area of about 226 square miles.

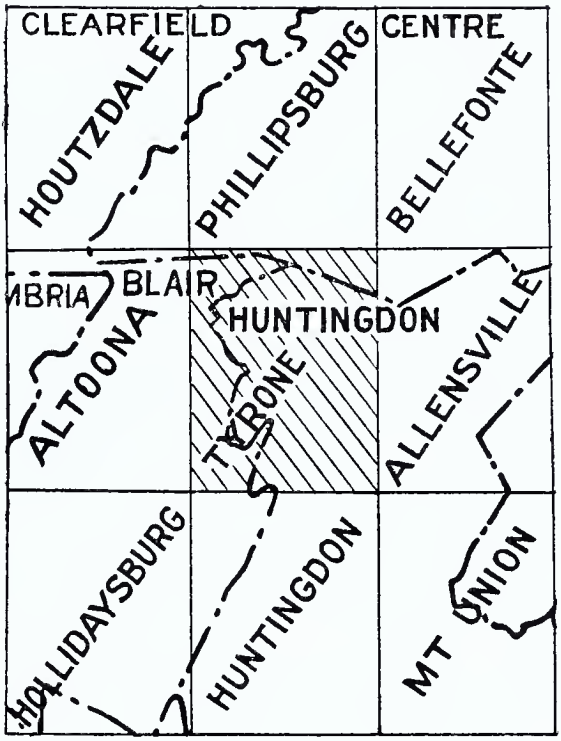


Figure 1. Index map showing the location of the Tyrone quadrangle, Pennsylvania

GENERAL RELATIONS

As shown on the sketch map Figure 2, this area lies mostly in the Ridge and Valley section of the Appalachian Province, but extends into the Allegheny Mountain section of the Appalachian Plateau in the northwest corner. The Appalachian Valley and Plateaus are parts

of a still larger division of the eastern United States known as the Appalachian Highlands, which extend from the Coastal Plain on the east to the Interior Plain of the Mississippi Valley on the west.[1]

The entire Highlands region within these boundaries has had a common development history, both geologic and topographic. Owing to the intimate relation of the Tyrone quadrangle to the Appalachian Highlands resulting from their common history, that region will be briefly described here.

Appalachian Highlands.—The Appalachian Highlands are, on the basis of differences of rocks, structure, and topography, divided into the following subregions, called provinces, named from east to west, Piedmont, Blue Ridge, Appalachian Valley, Appalachian Plateau and Interior Low Plateau.

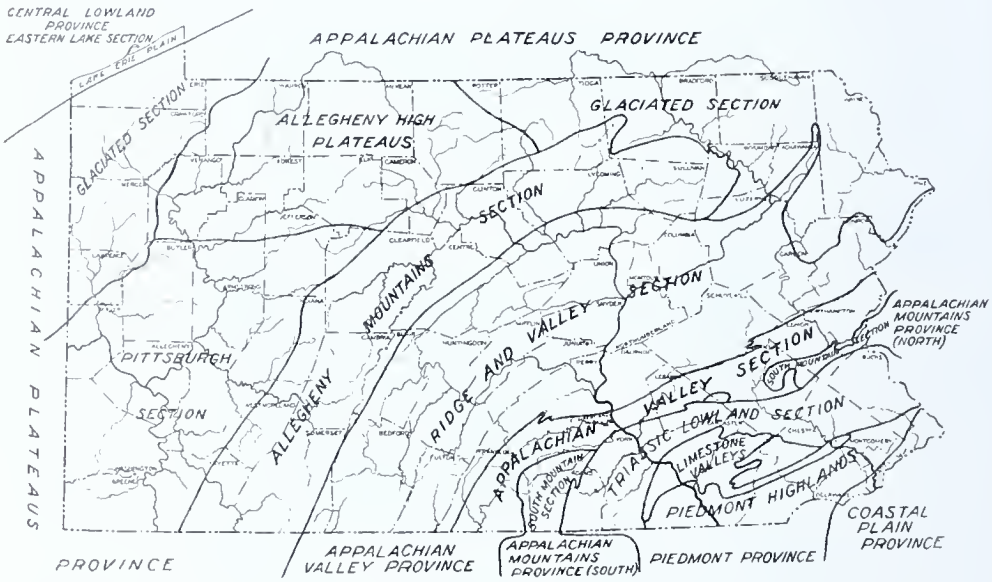


Figure 2. Physiographic divisions of Pennsylvania (after Fenneman).

The Piedmont is a rolling upland with a fairly uniform surface sloping from a general altitude of 1,000 feet at the eastern foot of the Blue Ridge to an altitude of 500 feet at the western boundary of the Coastal Plain, the well known "Fall line" of the southeastern states. The Piedmont is underlain by highly deformed igneous and metamorphic rocks.

The Blue Ridge Province includes the well known Blue Ridge of Virginia and the broader mountain region of western North Carolina and eastern Tennessee. It culminates to the north in the South Mountain of Adams and Franklin Counties. The Blue Ridge Province is underlain by crumpled igneous and metamorphic rocks, and by quartzite, which, through their resistance to erosion, cause the elevated and rugged nature of the area.

[1] Fenneman, N. M., Physiographic divisions of the United States: Assoc. Am. Geographers Annals, vol. IV, pp. 19-98, 1917.

The Appalachian Valley Province is of especial interest because the Tyrone quadrangle is mainly located within it. This province is rather lower on the whole than the Blue Ridge on the southeast and the Appalachian Plateaus on the northwest. Its northwestern boundary is formed by the high scarp known as the Allegheny Front. (See Pl. 4, A.) This scarp ascends to the Allegheny Mountain in the northwest corner of the Tyrone quadrangle, and is a conspicuous feature extending unbrokenly from the vicinity of Lock Haven south to and beyond the Maryland line. As thus bounded the Appalachian Valley is a belt 30 to 100 miles wide extending from New York to Alabama. It is underlain by sedimentary stratified rocks, sandstone, shale, limestone and dolomite, in great superposed sheets that have been folded and faulted by great horizontal compressive forces apparently directed from the southeast. Where these upturned strata are limestone, wide rolling lands, such as Nittany, Cumberland, and Shenandoah valleys, have been formed through erosion during the millions of years since the upturning; where the highly inclined strata are hard sandstone, ridges have been formed standing above the valleys, such as Tussey and Bald Eagle Mountains which coincide with the outcrop of the hard Tuscarora quartzite.

West of the Appalachian Valley lie the Appalachian Plateaus which coincide in a general way with the eastern coal field of the United States. The eastern boundary in Pennsylvania is the Allegheny Front. The western boundary follows the southeastern shore of Lake Erie and thence extends southwestward to northeastern Alabama. This division is underlain by sandstone and shale with coal beds which, throughout most of the province, are but little disturbed from the nearly horizontal attitude in which they were deposited. The relatively flat strata of the Appalachian Plateaus stand in marked contrast to the strongly folded beds of the Ridge and Valley section. The general summit altitudes of the Appalachian Plateaus are about 500 to 800 feet above sea level in Alabama, rise to over 4,500 feet in eastern West Virginia and thence descend to 1,500 to 2,500 feet in northwestern Pennsylvania, the higher altitudes being on the eastern margin of the plateau. The part of the Appalachian Plateaus in Pennsylvania is called the Allegheny, that in West Virginia and Kentucky the Kanawha, and that in Tennessee and Alabama the Cumberland Plateau.

West of the Appalachian Plateaus are the Interior Low Plateaus. As this province of the Appalachian Highlands is distant from the Tyrone quadrangle, it will not be described here.

History of the Appalachian Highlands.—The superposed rock strata of the Appalachian Valley and Plateau provinces were formed as layers of sediments in a great interior sea, gulf or strait. Material for these sediments was derived from ancient land on the east whose western boundary lay along the present Blue Ridge of Virginia, South Mountain of Pennsylvania, and the Green Mountains of Vermont; from another land area that included the Adirondacks of New York and the areas of crystalline rocks in Canada north of the Great Lakes; and from a western land whose exact eastern boundary is unknown because it is now buried beneath the Paleozoic sediments.

Bounded by and partly enclosed by the land areas was a long but comparatively narrow channel known as the Appalachian Strait which extended from the region of the present Gulf of Mexico to that of the Gulf of St. Lawrence. In this narrow channel were laid down the oldest rocks of the Appalachian Valley. These rocks and others deposited at the same time in other parts of the world contain in significant abundance the oldest remains of animal life known upon the earth and hence mark the beginning of the Paleozoic era, the era of ancient life.

During all the Paleozoic time the interior of the eastern United States slowly subsided, the Appalachian Strait slowly expanded westward into an Appalachian Gulf. Finally it spread over the ancient land on the west whose elevated parts now appear in Missouri and Texas. The deeply buried parts of this land are now reached in places by the drill. From the lands bordering the Appalachian Gulf was derived the great body of sediments composing the present formations of shale, sandstone, conglomerate, limestone, and dolomite of the valley. This material was transported from the land by the streams either as mechanical sediment, clay, sand or gravel or in solution which permitted calcium carbonate and magnesium carbonate to be deposited and form limestone and dolomite. The accumulation of this sedimentary material continued through the immensely long Paleozoic time and finally filled up the gulf with deposits reaching in parts a thickness of 8 miles or more in the Appalachian Valley. The head of the Appalachian Gulf seems to have been in the vicinity of eastern New York, and in later Paleozoic time the greater body of sediments in the northeastern United States seems to have been derived from the region of the Adirondack Mountains and New England, which enclosed the head of the Appalachian Gulf. These sediments compose the great body of Devonian and Carboniferous rocks of Pennsylvania. While these rocks were accumulating the animals and plants underwent continuous change, so that the faunas and floras of successive ages were totally different in species from those of the preceding ages, which had become extinct.

The downward movement of the Appalachian region finally came to an end, and a reverse movement of uplift ensued which has continued more or less intermittently until the present. Accompanying the early periods of this upward movement great horizontal compression folded and faulted the flat sheets of rock and produced the existing structural features of the valley.

With the emergence of the Appalachian area above the sea into a land area the work of destruction set in and has continued ever since. The rocks disintegrated into soil which was washed away by the running water. During long periods of quiescence in which upward movement was for the time suspended the land was degraded to a surface approaching a plain, called a peneplain or almost a plain. On renewed uplift this course of events was repeated, and it is believed upon evidence that cannot be cited here that such uplifts and peneplanation have been several times repeated since the Appalachian revolution. The top of the Allegheny Mountains and even the top of the high ridges such as Bald Eagle and Tussey mountains, represent

one of the earliest peneplains which has been uplifted about 2,000 feet above the original peneplain level and dissected by subsequent erosion.[2] A younger peneplain is believed to be represented by the shelf-like upper surface of the eastern foot-hills of Allegheny Mountains as shown in Pl. 4, B. In very recent years the more than local significance of the lower peneplain levels has been questioned.[3] The present topography of the Appalachian Valley shows that the topographic and geologic features of the Tyrone quadrangle represent a stage in an immensely long course of development or evolution, some knowledge of which is necessary to an understanding of existing conditions which it is the object of this atlas to map and describe.

TOPOGRAPHY

Topography means the physical features of a country or its land forms, their shape, height, relief and sculpture. These physical features of the Tyrone quadrangle are represented on the topographic map by the brown contour lines, and the drainage by blue. The physical features of the area are described under the two heads of relief and drainage.

Relief

Relief is the difference in altitude or height of the different parts of a region. The highest point in the Tyrone quadrangle is 2,380 feet above sea level in the extreme northwest corner, and the lowest point is 620 feet above sea level on Juniata River near the southeast corner. The maximum relief is the difference between these two elevations, or 1,760 feet. In general the relief within the view of an observer anywhere but on the highest summits is much less than this. Thus in Bald Eagle Valley the relief looking northwestward up the valley of Vanscyoc Run to Allegheny Mountains is about 1,400 feet and looking southwestward to Bald Eagle Mountain 700 to 800 feet. In the comparatively rolling area between Bald Eagle and Tussey mountains the relief is 100 to 400 feet except in the southwest corner of the area, where Brush and Lock mountains rise 1,000 to 1,200 feet above the valley bottom. Except for the mountain sides and river bluffs the slopes are relatively low and the surface in that respect suitable to cultivation.

The striking topographic features of the quadrangle are the high parallel ridges, Bald Eagle, Brush, Lock, and Tussey mountains and Round Top and Leading Ridge. These owe their existence and parallel directions to the following circumstances. They each coincide with the outcrop of a stratum of hard and resistent sandstone standing in a vertical or highly inclined attitude. These strata are bounded on both sides by softer and more easily erodible strata which in the long continued erosion hitherto spoken of have been worn down faster than the hard sandstones outcropping on the ridges.

The Allegheny Front is an equally conspicious feature of the topography although but a small part of it crosses this quadrangle. Be-

[2] Ashley, Geo. H., Studies in Appalachian Mountain sculpture: Bull. Geol. Soc. Amer., vol. 46, pp. 1395-1436, 1935 (see plate 4).

[3] Ashley, Geo. H., Further studies of Appalachian Mountain sculpture: Bull. Geo. Soc. of Amer. (in press) and footnote on page 87 of this report.

yond the limits of the area both northeast and southwest it is a dominant feature of the landscape for many miles. Plate 4, A shows its northeast extension. A still more extensive exhibition of it to the southwest (left of Pl. 4, A) can be seen from a high point in Bald Eagle Valley such as the hill occupied by the cemetery in Tyrone. The broad rolling Nittany Valley proper between Bald Eagle and Tussey mountains is developed upon a great expanse of limestone and dolomite having no beds presenting notably different resistance to erosion, so that it has no striking topographic features. Yet a tendency to the formation of broad low ridges and lines of broad low knolls is perceptible. These elevations coincide with the outcrop of the thick Gatesburg dolomite, which contains many layers of sandstone yielding on decay a thick mantle of soil that retards the reduction by erosion of the areas upon which the formation crops out.

In comparison with the area last described the region southeast of Tussey Mountain is much more minutely dissected into low conical hills or even is reduced to a nearly smooth surface as shown in Plate 4C. Here the underlying strata are mainly soft shale and thin limestone complexly crumpled and having no strongly resistant beds to give a dominating topographic aspect to any part of the area.

Another feature of the topography is the occurrence of gaps cutting through the ridges, as at Tyrone, Spruce Creek and Water Street. The explanation of these seeming anomalies lies in the historic development of the drainage described in the chapter on geologic history.

The broad valleys and wide bottoms along the rivers southeast of Alfarata and Barree are in strong contrast to the narrow valleys and flood plains through Tussey Mountain and the country west of it. The difference is due to the nature of the rocks in the two areas. The broad valleys are eroded in shale with thin layers of limestone, whereas the narrow gorges are in resistant sandstone and thick-bedded limestone and dolomite. In the areas of softer rocks the rivers have widened their valleys, but in the harder rocks their energies have been entirely absorbed in deepening their valleys.

Drainage

The whole area is drained to the Atlantic by streams belonging to the Susquehanna system. The streams are completely adjusted and have reached topographic maturity, as is shown by the absence of falls or rocky rapids in the main streams. In fact the streams seem to have been aggrading their valleys in recent times for even in the gorges through the mountain ridges, deposits of gravel and alluvium cover the bedrock to considerable depth, which could not be true in a rapidly eroding stream.

The gradient or rate of fall of the main streams is as follows:

Juniata River falls from 880 feet at Tyrone to 620 feet at Huntingdon. Total fall 260 feet in about 18 miles, or 14½ feet to the mile.

Bald Eagle Creek falls from 1,100 feet at the mouth of California Hollow to 880 feet at Tyrone. Total fall 220 feet in about 8 miles or 27½ feet per mile.

Spruce Creek falls from 1,060 feet at Pennsylvania Furnace to 760 feet at Spruce Creek. Total fall 300 feet in about 20 miles or 15 feet per mile.

An interesting feature of the drainage is the comparative scarcity of perennial surface streams in the broad valley belt between Bald Eagle and Tussey mountains as compared with the remaining areas of the quadrangle. This feature is due to the solution channels in the underlying limestone and dolomite which provide subterranean passageways for movement of the water. A stream may disappear below the surface, and after running a distance in an underground conduit, reappear as a large spring. As shown upon the topographic map, southwest of Union Furnace two tributaries of Sinking Run disappear into the ground within two miles to the southwest of Arch Spring and emerge at Arch Spring from a large opening in the limestone which suggests the name of the place. Such drainage phenomena are common in limestone areas.

DESCRIPTIVE GEOLOGY

The geologic formations of the Tyrone area are composed of marine and deltaic sedimentary and stratified rocks. They all belong in the Paleozoic, one of the major divisions of the earth's strata. Paleozoic means ancient life, and these formations are so named because they contain fossil remains of extinct plants and animals which differ in marked degree from the creatures of later geologic time and of the present day. The Paleozoic formations are customarily subdivided into the Cambrian, Ordovician, Silurian, Devonian and Carboniferous systems, named in ascending order. The author would modify this classification to read as follows: Cambrian, Ozarkian, Canadian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian and Permian systems. All up to and including the Mississippian are represented in the Tyrone area, and the Pennsylvanian (Coal Measures) comes in a few miles northwest of the Allegheny Mountains.

The total thickness of strata cropping out in the quadrangle is about 22,000 feet. This great mass is divided into 37 formations or stratigraphic units which have a wide geographic extent in central Pennsylvania and each of which is represented on the areal geology map by a separate color or pattern. Certain further subdivisions of formations into members are not shown on the map because too thin, as the Castanea sandstone. The general stratigraphic succession, character and thickness of the formations are exhibited in the generalized columnar section. Each is described under the head, Stratigraphy.

STRATIGRAPHY

CAMBRIAN SYSTEM

The Cambrian system was named from Cambria, the ancient name of Wales, in which country the system was first recognized in 1835, 100 years ago. In the Cambrian system are grouped all the Paleozoic rocks of the earth's crust which contain the oldest well known forms

of life. Any rocks containing these forms of life anywhere in the world become by virtue of that very fact members of the Cambrian system. The classification is purely chronological and is based upon the assumption that the general types of life characterizing the Cambrian of Wales lived contemporaneously in all the other parts of the earth in which rocks are found that contain the fossil remains of those types.

In the Tyrone quadrangle five formations of the Cambrian system are differentiated, namely: Pleasant Hill limestone, Warrior limestone, Gatesburg dolomite, Mines dolomite and Larke dolomite.

PLEASANT HILL LIMESTONE

This formation was named from Pleasant Hill Church about one mile northwest of Henrietta, Blair County. In the Tyrone quadrangle the Pleasant Hill is known only in a narrow strip extending about 1½ miles south from Grazier Mill, which is about one mile northeast of Huntingdon Furnace. It is in faulted contact with the Nittany dolomite on the east and, so far as could be observed, in contact with the Gatesburg formation on the north and west. The Warrior limestone, about 1,200 feet thick, which normally belongs between them, is absent here. The shape of the contact is such that this could hardly result from displacement (faulting) and suggests an unconformity. This explanation is open to the objection that the Warrior is present beneath the Gatesburg three-fourths of a mile northwest of Grazier Mill. However, that is the best explanation in view of all the known facts. It implies a sharp uplift of the sea floor over an area in the vicinity of Grazier Mill after the deposition of the Pleasant Hill so that the Warrior limestone was not deposited there.

There are good exposures of the Pleasant Hill limestone in the immediate vicinity of Grazier Mill, on the ridge about one-half mile to the south-southeast of the mill, by the roadside one-half mile east of Huntingdon Furnace, and on the east slope of the ridge three-fourths of a mile southeast of Huntingdon Furnace at the southern extremity of the strip mapped as Pleasant Hill. The Pleasant Hill limestone in this area is composed of more or less argillaceous and siliceous limestone inclosing beds and layers of purer rock. The clayey matter, on weathering, shows as gray bands or splotches on the mainly blue layers, giving the mass a mottled aspect. On complete weathering much of the rock loses its calcareous content through leaching and finally splits up into rusty chips. Much of the Pleasant Hill at Pleasant Hill Church, one mile north of Henrietta, is likewise argillaceous, breaking down into a shaly mass. At Pleasant Hill, however, there is a thick mass of pure fossiliferous limestone at the top of the formation, and 5 feet of similar limestone are exposed about 1,000 feet northwest of Grazier Mill. Some thin layers of highly oolitic limestone are scattered through the mass.

Some of the layers of the Pleasant Hill limestone in the immediate vicinity of Grazier Mill are highly fossiliferous and a few fossils occur all along the outcrop. Most of the fossils are trilobites, but a few linguloid brachiopods were found.

The fossils have not been fully studied but species of Alokistocare, Asaphiscus, Neolenus and Blania have been recognized by Resser. All but Asaphiscus occur at Pleasant Hill, and a specimen of Neolenus has been found in a small area of the formation cropping out about 1½ miles northwest of Williamsburg and about the same distance south of the Tyrone quadrangle. The fossils are sufficient evidence that the limestone here described is the Pleasant Hill and that it is of Middle Cambrian age.

WARRIOR LIMESTONE

The Warrior limestone is named from Warriorsmark Creek along which it crops out and is partly exposed for about two miles southeast of Warriorsmark. This formation is about 1,200 feet thick. It is composed of interbedded limestone and dolomite, with thin layers of siliceous shale or shaly sandstone.

Fifteen feet of limestone is exposed in an old quarry just north of the intersection of the road to Dungarvin, 1½ miles north-northeast of Warriorsmark. Limestone estimated to be 25 feet thick and underlain by thin-layered dolomite is exposed in a low bluff by the roadside on Warriorsmark Creek two miles southeast of Warriorsmark. Slabs of blue limestone are sparingly distributed over the surface southwest of Warriorsmark Creek to the south end of the mapped area of the formation. So far as exposed, the limestone of the Warrior appears to be in beds of greater or less thickness intercalated in a predominant mass of dolomite or magnesian limestone. The layers of limestone are generally less than a foot thick, of a fine or compact texture, and of a prevailing blue color suggesting a pure calcium carbonate. Oolitic layers are fairly common, the oolitic grains in some cases being of rather large size and preserving radial as well as concentric structure. The dolomitic phases of the formation are shown in a quarry on the south bluff of the creek a half mile southeast of Warriorsmark, and to a thickness of about 50 feet on the railroad at the curve three-fourths of a mile west of Dungarvin. Here the rock is mostly thick-bedded and looks like limestone, but shows its highly magnesian composition on testing with acid. Thin streaks and layers of limestone occur here, however, and thin partings of sandy shaly rock. The rock at this exposure appears to be typical of the formation throughout its full thickness. On the bluff north of the Frankstown Branch of Juniata River about one mile northwest of Williamsburg, south of the Tyrone quadrangle, are at least two layers of limestone five feet or more thick, crowded with perfectly rounded quartz grains which give to the layers such hardness that they stand out on the face of the bluff like vertical ribs. No such rock has been observed in the Warrior of this area.

The Warrior has yielded a considerable number of genera and species of trilobites in this area, in the Bellefonte quadrangle to the northeast, and in the Huntingdon, Hollidaysburg and Everett quadrangles to the south, but they have not been adequately studied. A few forms have been identified, such as several species of *Kingstonia*, *Menomonia avitas*, and a rare form known as *Pemphigaspis*. The genus *Kingstonia* occurs in the southern Appalachian region in limestone in

the Nolichucky shale, the genotype having been found in these beds near Knoxville, Tennessee. The only other locality for *Pemphigaspis* is Wisconsin, where it is rare and occurs in close association with *Crepicephalus* in the lower part of the Upper Cambrian of that state. In the southern Appalachian region the trilobite genus *Crepicephalus* occurs only in the Nolichucky shale overlying the Maryville limestone or in the upper part of the Conasauga formation equivalent to the Nolichucky shale. It would appear therefore that the Warrior corresponds in part to the Nolichucky shale, which is lower Upper Cambrian according to the standard Upper Cambrian section of Wisconsin. Possibly also it corresponds in part to the Maryville limestone.

HIATUS

The upper formations of the Upper Cambrian as defined in Wisconsin are absent in central Pennsylvania and there is a hiatus of considerable magnitude between the Warrior limestone and the overlying Gatesburg formation.

GATESBURG FORMATION

The Gatesburg formation, named by E. S. Moore from Gatesburg Ridge in the southwest corner of the Bellefonte quadrangle, crops out in an elongate area extending southwest from the northeast corner of the quadrangle to beyond Juniata River in the vicinity of Birmingham and in three small areas in the southwest corner of the quadrangle, beyond which the outcrop expands into a wide belt extending southwest across the Huntingdon and Hollidaysburg quadrangles. The best exposure of the Gatesburg in the Tyrone quadrangle is along the highway and in the railroad cuts between Shoenberger and Birmingham. (See Pl. 5.) The formation is about 1,750 feet thick, as measured on the bluff of Frankstown Branch of the Juniata just northwest of Williamsburg (Huntingdon quadrangle), where the beds are nearly vertical.

The Gatesburg is composed predominantly of dolomite, thick-bedded, coarsely crystalline, and of a steely blue color. There is a smaller amount of thin-bedded, gray, fine-grained dolomite, which however may be in the upper part of the Warrior, and which is best exposed in the railroad cut next southeast of the station at Birmingham. Intercalated in the dolomite are many layers of quartzite, some of which are as much as 10 feet thick. This quartzite is the distinguishing feature of the Gatesburg. Although only a relatively small proportion of the whole thickness, the quartzite layers yield on decomposition an abundance of quartz sand and boulders. These mantle the surface underlain by the Gatesburg so completely that to one unacquainted with the real nature of the formation it would appear that the ground is underlain only by quartzite. The sand is utilized in the region for mortar, and pits as much as 20 feet deep have in places been opened in nearly pure sand. This sandy mantle, although present everywhere on the outcrop of the Gatesburg, is especially well displayed and impressive in the scrub-covered barrens of Gatesburg Ridge in the Bellefonte quadrangle. In the Huntingdon quadrangle, adjoining the Tyrone quadrangle on the south, the lower 500 feet or

Gatesburg formation. Bluff of the Little Juniata River ¼ mile northwest of Shoenberger. Looking northeast.

so of the Gatesburg seems to be nearly all dolomite of typical Gatesburg character but without quartzite.

In the Hollidaysburg and Huntingdon quadrangles there is also near the middle of the Gatesburg about 100 feet of thin-bedded limestone. These beds have been named the Ore Hill limestone member from Ore Hill in the southwest part of the Hollidaysburg quadrangle. The Ore Hill member is widely distributed in the quadrangles named. The limestone is fossiliferous, the fossils being mainly trilobites. The rest of the Gatesburg is non-fossiliferous.

About 15 or 20 genera of trilobites have been distinguished in the Ore Hill fauna. Among them are *Housia, Irvingella, Elvinia, Saratogia* and *Burnettia.* Resser correlates the Ore Hill with the Ironton member of the Upper Cambrian Franconia formation of Wisconsin and thinks it of about the same age as the Hoyt limestone at the top of the Potsdam sandstone of the Lake Champlain region of northeastern New York. So the Gatesburg may be considered as latest Cambrian in age. The writer correlates the Gatesburg with the Conococheague limestone in similar sequence in the Mercersburg-Chambersburg area in Pennsylvania. Ulrich, basing his conclusions upon the Ore Hill trilobites, thinks the Gatesburg is older than the Conococheague.

MINES DOLOMITE

The Mines dolomite was named from the old mining town about five miles southwest of Williamsburg, Blair County. The Mines dolomite is persistent in the Tyrone quadrangle and is about 250 feet thick. The best exposure seen in the Tyrone quadrangle is in the bluff south of Little Juniata River opposite Shoenberger station. It is also partly exposed on the spur between the two roads just south of Williamsburg, a few miles south of the Tyrone quadrangle. A layer of dolomite taken as the bottom of the formation and crowded with the hollow molds of gastropods is exposed on the point of the spur about 100 feet above the level of the town. The spur is occupied by the Mines only, beds of the dolomite are exposed from place to place and, as no foreign material has been washed upon it, the surface material has been derived entirely from the underlying beds. Consequently a good idea of the cherty, non-quartzitic character of the formation can be obtained at this place.

The Mines dolomite differs from the Gatesburg in two particulars that warrant its separation as a distinct formation. It includes no quartzite so far as known, and it yields an abundance of chert which marks the areas underlain by it. The chert is scoriaceous and hard to the touch. Much of it is oolitic, the oolitic grains being large and commonly black and set in a white matrix. The dolomite of the formation differs in no respect from that of the Gatesburg, however.

The Mines has yielded a few poorly preserved gastropods, and some of the cherts are silicified heads of *Cryptozoa,* including large globular or hemispherical masses like *C. proliferum.* Some slabby pieces are made up of cylindrical individuals and resemble *C. undulatum.* Both forms, but particularly the last, occur in the Copper Ridge chert of the southern Appalachian Valley. The gastropods occur

in the ordinary coarse steely blue dolomite and were found in boulders, first, on the top of the low spur about 1,500 feet northeast of the railroad station at Shoenberger and, second, on the slope of the southeast side of the hollow about one mile southwest of Shoenberger. These two occurrences are in the same belt and in strike with each other, indicating the same layer as their source.

One of the species is *Sinuopea umbilicata* or at least not readily distinguishable from that species in its state of preservation as an interior mold. The molds at Williamsburg at the base of the Mines as mentioned above are believed to represent the same species. *Sinuopea umbilicata* occurs in the Van Buren dolomite of the "Ozarkian" of Missouri, and the Van Buren horizon is recognized in the lower half of the Copper Ridge dolomite of the Birmingham district, Alabama.

In view of the facts above stated the Mines is tentatively correlated with the Copper Ridge.

LARKE DOLOMITE

The Larke dolomite was named from Larke, three miles south of Williamsburg, Blair County. The typical Larke is a dolomite distinguished from the Mines and Gatesburg by the absence of both quartzite and chert.

In the Tyrone quadrangle beds somewhat doubtfully referred to the Larke crop out only in three small areas in the southwest quarter of the area. Here as seen at a few places along the belt mapped as Larke three-fourths of a mile northwest of Blairfour are thin, limy-looking beds, probably highly magnesian, lying between the Mines and Nittany dolomites. These limy-looking beds suggest the character of the lower part of the Larke in the vicinity of Williamsburg where the Larke also lies between the Mines and Nittany dolomites, and so the beds under description here are regarded as probably representing the Larke. From the apparent width of the outcrop and steep dip of these beds, they are estimated to be at least 250 feet thick.

On the evidence of a few fossils found in the Hollidaysburg-Huntingdon area the Larke is correlated with the Chepultepec dolomite of Alabama and with the upper part at least of the Little Falls dolomite of northeastern New York, these formations being the terminal units of the late Cambrian or "Ozarkian" system in their respective regions. One of the fossils of the Larke is a single specimen of *Helicotoma uniangulata* found near Ore Hill, Blair County. This species is the principal guide fossil of the Chepultepec and Little Falls in the eastern United States.

Helicotoma winonaensis and *Hemithecella expansa* belonging in the *Helicotoma uniangulata* zone have been found in limestone closely associated with Stonehenge limestone in the southwestern corner of the adjacent Bellefonte quadrangle. This occurrence may represent the Larke dolomite in that area.

ORDOVICIAN SYSTEM

The Ordovician system in central Pennsylvania, according to the usage of the United States Geological Survey, includes in ascending

order the following formations: Stonehenge limestone, Nittany dolomite, Axemann limestone, Bellefonte dolomite, Carlim limestone with the Lemont argillaceous limestone member at the top, Lowville limestone, Rodman imestone, Trenton limestone, Reedsville shale, Oswego sandstone, and Juniata formation. The Stonehenge, Nittany, Axemann and Bellefonte units constitute the Beekmantown group as commonly understood. Ulrich advocates raising this group to the rank of a system which he names the Canadian system. With this proposal the present writer is in accord. Also, Ulrich includes the Juniata formation in the Silurian system.

STONEHENGE LIMESTONE

The Stonehenge limestone was named from the village of that name two miles east of Chambersburg, Franklin County. As the Larke dolomite seems to be absent from most of the area the Stonehenge succeeds the Mines dolomite unconformably. However, it is possible that the chert-free Larke may be represented by chert-bearing beds included in the Mines where the Larke is not recognizable. The Stonehenge is about 400 feet thick in this quadrangle.

The Stonehenge crops out in the Tyrone quadrangle along a strip extending from Honest Hollow northwest of Birmingham to the Birmingham fault 1 mile northeast of Warriorsmark, and in several narrow strips along a relatively narrow belt extending from the northeast corner of the quadrangle diagonally southwest to the Juniata River a short distance west of Spruce Creek. The best exhibits are on a low spur just west of highway No. 550 and just north of Eyer, on the north bank of the Juniata River at the road forks ⅓ mile northwest of Spruce Creek, on a side road leading northwest from the main road 1 mile north of Spruce Creek and ¼ mile northwest of the intersection, along the road leading northwest from Shoenberger, and in the northeast corner of the quadrangle in the ravine 1 mile due west of Pennsylvania Furnace, where a thickness of 300 feet is exposed; at Graysville; and in an old quarry just north of Baileyville 2½ miles northeast of Graysville where it was once quarried for flux in Pennsylvania Furnace. The basal shaly beds with *Finckelnburgia* and *Aerograptus* are exposed in an old quarry 2 miles southwest of Waddle in the Bellefonte quadrangle.

The Stonehenge is composed mainly of thick and thin-bedded blue limestone but has a subordinate amount of dolomite. Striped or ribbony layers and layers of edgewise conglomerate are common. At an old quarry on the road ¼ of a mile northeast of Shoenberger station the following section is shown:

	Feet
Limestone, rather thick-bedded	30
Dolomite, thick-bedded, coarsely crystalline, blue	20
Limestone, thin-bedded, with layers of edgewise conglomerate	60

In places on the Bellefonte quadrangle adjoining the Tyrone on the northeast there is a considerable thickness of calcareous shale in the basal part. Locally, as on Spring Creek, about 5 miles southeast of

Bellefonte, thick-bedded dolomite of Gatesburg character occurs apparently about 200 feet above the base.

The following fossils have been collected from the Stonehenge limestone. Most of them occur in the outcrop north of the highway opposite the mouth of Honest Hollow ½ mile west of Birmingham but several of them are generally present at all exposures of the formation.

Finckelnburgia plicata Ulrich and Bridge, common
Schizambon pennsylvanicum Ulrich and Bridge, rare
Bellerophon calcifera Cleland ?
Eccyliomphalus multiseptarius Cleland
Ophileta levata Vanuxem
Raphistoma obtusum Cleland ?
Clelandia parabola (Cleland)
Symphysurus convexus (Cleland)

While some of the names are questioned there is but slight doubt that the identifications are correct. All the species except the first two occur in the Tribes Hill limestone of New York which is classed as the basal member of the Beekmantown group. In addition two species of *Ribeiria, R. calcifera* and *R. parva* occur in the Stonehenge in the Bellefonte region. *Ribeiria* is elsewhere known in the eastern United States only in the Tribes Hill limestone. The Stonehenge therefore can surely be correlated with Tribes Hill.

Another significant fossil for correlation is *Aerograptus (Dictyonema) furciferus* Ruedemann, found in the basal shaly beds of the Stonehenge in the Bellefonte region. This fossil is known elsewhere only in the *Tetragraptus* zone in the lower part of the beds exposed on the Deep Kill, a small stream entering the Hudson River from the east in the northwestern part of Rensselaer County, New York. The beds of this zone are classed as lower Beekmantown, hence the occurrence of *Aerograptus* in the Stonehenge is additional evidence of its lower Beekmantown ("Canadian") age.

Another interesting fossil of the Stonehenge is the trilobite *Bellefontia (Hemigyraspis) collieana* (Raymond). It is abundant in the upper 28 feet of the Stonehenge at Nittany Furnace about one mile southeast of Bellefonte. The genus *Bellefontia* (Ulrich) was established to include trilobite remains that had been referred to *Hemigyraspis* and *Asaphus* by various authors.

NITTANY DOLOMITE

The Nittany dolomite was named by Ulrich from Nittany Furnace one mile southeast of Bellefonte, Centre County, Pennsylvania. The Nittany is the mass of dolomite between the Stonehenge limestone below and the Axemann limestone above. Where both the Stonehenge and Axemann are present its limits are easily determined, but where the Axemann is absent or not exposed, as happens in places, the separation of the Nittany from the overlying Bellefonte dolomite of similar lithologic character cannot be made with certainty. In such cases a boundary line has been drawn which separates the entire Nittany and Bellefonte mass into nearly equal parts as it is known that the Nittany and Bellefonte are of about equal thickness in the Tyrone

quadrangle. The Axemann limestone when present is near the middle of the mass. The thickness of the Nittany dolomite in the Tyrone quadrangle is about 1,250 feet.

In this quadrangle the Nittany crops out in several belts lying diagonally across the area from the northeast to the southwest corner. There are clean-cut exposures of the formation along the Pennsylvania Railroad and along the highways between Shoenberger and Spruce Creek.

The Nittany is quite uniformly a dolomite prevailingly rather thick-bedded, medium to fine textured and light and dark gray, the latter predominating. An occasional layer has small nodules of black chert. On weathering, the entire formation or definite layers in it yield a profusion of dense, tough, light gray chert which is in many places plentifully scattered over the surface underlain by the formation. Some of this chert is oolitic, but such chert usually differs from the oolitic chert of the Mines dolomite in that the oolitic grains are smaller and white and inclosed in a dark matrix, whereas the grains in the Mines are generally larger and black in a white matrix.

The Nittany dolomite is one of the most widely distributed units geographically in the entire Paleozoic succession. It is marked by a characteristic genus of gastropods, of which *Ophileta compacta* Salter is the type. This fossil genus is not *Ophileta,* however, and has been renamed by Ulrich *Lecanospira.* There are several species and so far as known all confined to this geologic horizon. The fossils are rare and are found almost entirely in residual chert. Another diagnostic fossil is *Roubidouxia umbilicata* Ulrich and Bridge. It occurs in association with *Lecanospira,* often in the same piece of chert, throughout the Appalachian Valley and in Missouri in the Roubidoux limestone, from which it receives its name.

As marked by *Lecanospira,* strata belonging to this horizon have been recognized in the northwest highlands of Scotland, in Newfoundland, in Canada, in northeastern New York, throughout the entire length and breadth of the Appalachian Valley Province from Pennsylvania to Alabama, and in southern Missouri. In northeastern New York *Lecanospira (Ophileta) complanata* (Whitfield)[4] is an abundant fossil in about 40 feet of limestone, partly sandy, exposed 1½ miles north of Beekmantown station on the Delaware and Hudson Railroad 3 miles north of Plattsburg, N. Y. Thus the Nittany certainly includes the equivalent of part of the typical Beekmantown.

AXEMANN LIMESTONE

The Axemann limestone is named from Axemann, a village 2 miles southeast of Bellefonte, Centre County. The name was a rather unfortunate choice because the formation crops out about 1 mile southeast of the village while the Stonehenge limestone crops out and is well exposed at the village. The best exhibitions of the Axemann in and near the Tyrone area are on Frankstown Branch just north of Mount Etna, on the bluff of the Juniata River and northward ¾ mile west of Spruce Creek, and along highway 56 1½ to 2½

[4] Whitfield, R. P., Am. Mus. Nat. Hist. Bull., vol. II, Pl. 7, figs. 18-25, 1889.

miles southwest of Graysville. The formation is very inconstant in its outcrop, not a trace of it to be found for long stretches. Probably it is absent in such stretches, owing to non-deposition; but it may be represented by a dolomitic facies indistinguishable from the dolomite of the Nittany and Bellefonte formations between which it normally lies. An occasional fossil found in dolomite at or near its horizon suggests the latter explanation of the absence of the Axemann at least as a limestone.

The Axemann is predominantly blue, medium-bedded, moderately fossiliferous limestone but includes layers of dolomite. Some of the limestone layers are conglomeratic with pebbles of limestone.

The thickness of the Axemann ranges from a few feet to possibly 100 feet as in the large area ¾ mile northwest of Spruce Creek.

Among the more common fossils of the Axemann limestone in Blair, Huntingdon, and Centre counties are *Diparalasma* cf. *D. elegantula* Butts, *Coelocaulus* cf. *C. linearis, Turritoma* cf. *T. acrea, Hormotoma artemesia, Maclurea affinis, Ophileta (Liospira) strigata, Bathyurus* 4 sp., *Bolbocephalus* sp., and *Ribeiria* n. sp.

The *Diparalasma, Ophileta*, and *Maclurea affinis* seem to be more common throughout the extent of the formation than any of the others. Limestone showing many specimens of *Ophileta strigata* is exposed for a considerable distance along the highway 45, about 1 mile northeast of Cool Run School and 2 miles southwest of Graysville. *Maclurea affinis* occurs in the Beckmantown of Keppel Island, Newfoundland, and at Fort Cassin, Vermont. According to Ulrich, two of the four species of *Bathyurus* are closely related to or identical with undescribed species from the limestone at Fort Cassin. The genus *Bolbocephalus* is elsewhere reported only from Fort Cassin. It seems that the Axemann may occupy about the same stratigraphic level as the fossiliferous beds at Fort Cassin, although Ulrich assigns the Axemann to a somewhat lower level.

BELLEFONTE DOLOMITE

The Bellefonte dolomite is named from Bellefonte, Pennsylvania, which is largely located upon the outcrop of the formation. In the Tyrone area the Bellefonte occurs in several wide strips extending diagonally across the middle of the quadrangle. It is about 1,500 feet thick. Nearly all of it is exposed in all the belts where crossed by the Juniata River and Pennsylvania Railroad. Where the Axemann limestone is absent or can not be found or identified, the Bellefonte is arbitrarily separated from the underlying Nittany dolomite of similar lithologic character approximately at the horizon of the Axemann. The Bellefonte is a thick-bedded, evenly bedded gray dolomite of prevailing rather fine grain. In this area it does not yield much chert on weathering as does the Nittany.

Fossils are very rare in the Bellefonte dolomite. None have been found in this area, but a few have been found in the Bellefonte region and in the Huntingdon quadrangle south of the Tyrone quadrangle. The most significant fossils are a species of *Ceratopea* found a short distance west of Covedale in the Huntingdon quadrangle, and a large

species of *Eurystonites* found near Boalsburg in the Bellefonte quadrangle. The genus *Ceratopea?* is entirely characteristic of Beekmantown rocks of post-Nittany age such as the Newala limestone of Alabama and the Cotter and Powell limestones of Arkansas in which rare specimens of *Eurystomites* also occur. *Eurystomites* and allied cephalopods are also a prominent constituent of the fauna of the limestone at Fort Cassin, Vermont. It is certain therefore that the Bellefonte is of Beekmantown age and probable that it is equivalent to, or includes the representatives of, beds of post middle Beekmantown age mentioned above.

CHAZY GROUP

The Chazy group in central Pennsylvania is represented by the Carlim limestone and its argillaceous limestone member at the top named the Lemont argillaceous limestone member.

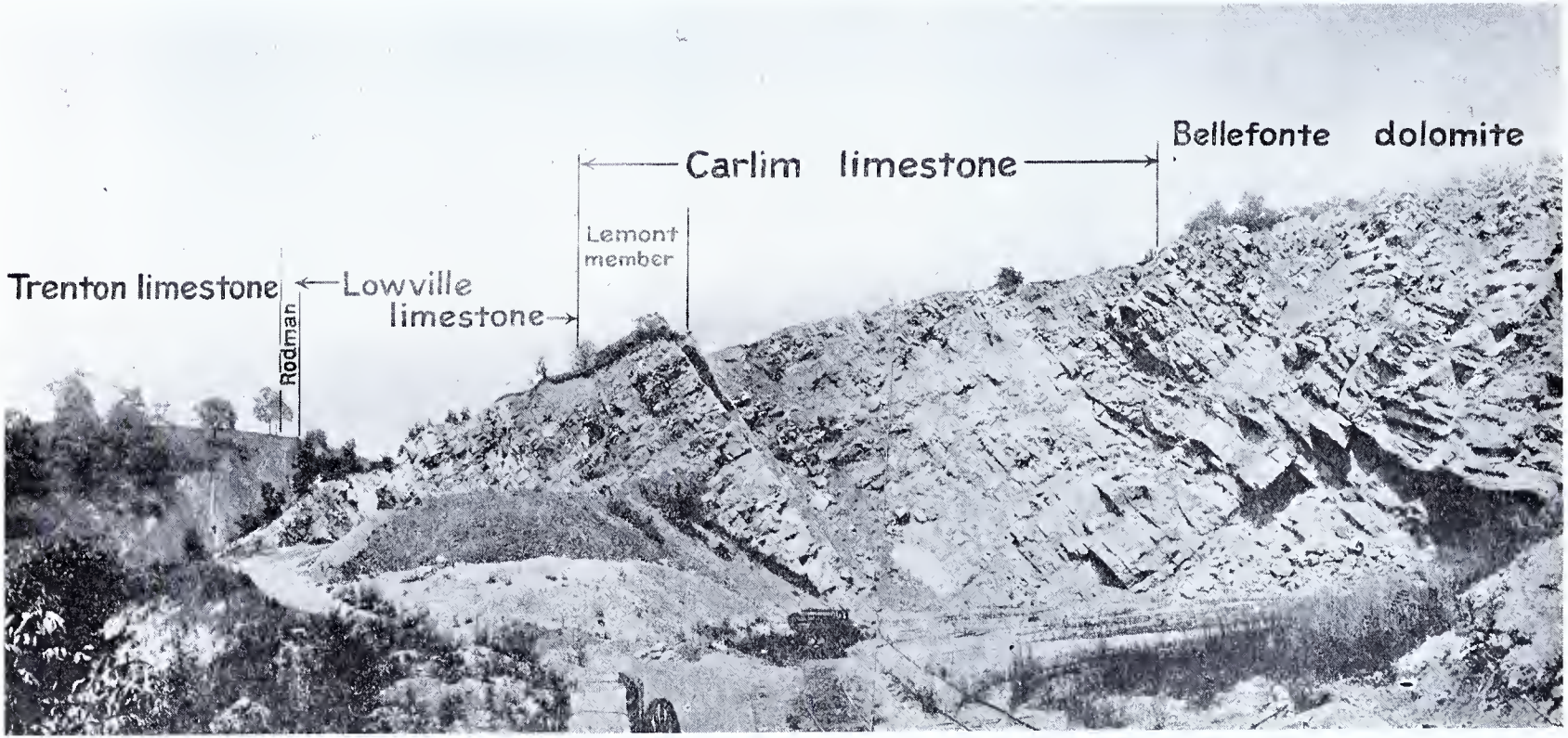
CARLIM LIMESTONE

The Carlim receives its name from the old quarry town of Carlim on the Petersburg Branch of the Pennsylvania Railroad one mile south of the quadrangle. The thickness of the Carlim, including the Lemont member, is 250 to 300 feet.

The Carlim is exposed in the quarries on Elk Run and at Union Furnace. It is the lower 200 feet or more of the quarry rock lying between the dolomite of the Bellefonte below and the Lowville limestone above. Its top is marked by the impure Lemont member which in places is not removed in quarries for flux rock but is left standing as a rib projecting from the bottom of the quarry as shown in Plates 6 and 7, especially in 7A. At the bottom of the Carlim an alternation of layers of dolomite and scantily fossiliferous blue limestone generally occurs through a thickness of about 10 feet, immediately in contact with the Bellefonte dolomite. As exposed along the road to Eden Hill School on the southeast side of the big quarry at Union Furnace these passage beds are estimated to be 50 feet thick and are composed mostly of thick-bedded dolomite with at least four layers of blue limestone 1 to 4 feet thick, with ostracodes. Above these passage beds there is quite commonly a small thickness of very brittle black limestone with ostracoda and a strophomenoid brachiopod. The rest of the formation is prevailing medium thick-bedded bluish gray to dark, generally compact, sparingly fossiliferous limestone. This is succeeded at the top by the Lemont argillaceous limestone member.

Lemont argillaceous limestone member.—This terminal part of the Carlim, named from Lemont near State College, Centre County, is composed of argillaceous and siliceous, dark, in part shelly, fossiliferous limestone about 40 feet thick. See Plate 7A. It thins northward along the strip at the southeast base of Bald Eagle Mountain and at Bellefonte is only about 12 feet thick. At that place there is a bed of bentonite below and one above it, each a few inches to 1 foot thick. The bentonite is a claylike substance derived from a volcanic ash.

In the layer of limestone at the bottom of the 50 feet of the mainly heavy dolomite at the base of the Carlim at the quarry at Union Furnace mentioned above is an abundance of ostracodes of the genus



View in limestone quarry on Elk Run west of Ironville. Strata overturned. Sequence from left to right, Trenton limestone, Rodman limestone (see also pl. 8 A), Lowville limestone, Lemont member of the Carlim limestone, Carlim limestone, and Bellefonte dolomite. Looking northeast.

Isochilina. This is a different, less elongate species than the common Chazy form *I. ottawa* Jones. However, it has no resemblance to the strongly punctate *Isochilina seelyi* of the Beekmantown of Vermont and so is probably best regarded as a Chazy form. In the brittle black limestone next above the basal dolomite and limestone layers small smooth ostracodes are common, some examples of which are species of *Isochilina* also probably different from the species mentioned above. With these is a brachiopod identical with or very similar to *Strophomena prisca* Raymond of the lower Chazy beds on Valcour Island, Lake Champlain. Fifty feet or so still higher, in dark compact limestone, occur *Helicotoma tennesseensis, Crytodonta* sp. ?, *Leperditia* aff. *L. fabulites*?, and *Coelochilina (Eurychilina) aequalis?*. Fairly large collections have been made from the main body of the Carlim at Roaring Spring, Blair County, which include *Protorhyncha ridleyana, Bathyurus* aff. *B. superbus, Schmidtella crassimarginata, Krausella subequalis, Eurychilina* sp., and several species of *Leperditia.* The evidence of these fossils tends to indicate that the part of the Carlim below the Lemont member is to be correlated with the lower Chazy of Champlain Valley, New York, and the lower Stones River of the Nashville Basin, Tennessee.

The Lemont member, which is generally highly fossiliferous, carries such fossils as *Protorhyncha ridleyana, Hebertella vulgaris, Glyptorthis bellarugosa, Rafinesquina champlainensis,* and *Maclurea magna.* The last species, which has not been found in this area but is quite common in the Lemont at Lemont and Oak Hall, Centre County, and at Naginey, Mifflin County, is one of the best guide fossils of the middle Chazy, being characteristic of and confined to the Crown Point limestone of the Chazy of Champlain Valley. There seems no reasonable doubt that the Lemont member of the Carlim is the Pennsylvania equivalent of the Crown Point limestone.

UNCONFORMITY

In central Pennsylvania there are no formations corresponding to the Blount group of Ulrich in Virginia and east Tennessee which aggregates as a maximum 7,500 feet in thickness and which there lies between the Lenoir limestone below and the Bays sandstone above. As the Lenoir is about equivalent to the Lemont member of the Carlim limestone and the Bays is about equivalent to the Lowville limestone which immediately succeeds the Lemont, there is, in central Pennsylvania, an unconformity due to the absence of the Blount group. In other words, the time that elapsed between the deposition of the Lemont and Lowville was long enough for the deposition of about 7,500 feet of shale, sandstone, and limestone in eastern Tennessee. Notwithstanding this long time break between the formations they appear perfectly concordant in bedding (see Plates 6, 7B). This shows that no folding or emergence took place in the interval, for if the rocks below the Lowville had been folded or raised above sea and eroded, the even contact of the Lemont and Lowville would have been impossible[5].

[5] For further discussion of this subject see Butts, Charles, Variations in Appalachian stratigraphy: Washington Acad. Sci. Jour., vol. 18, no. 13, July 19, 1928.

A. Lemont limestone member of the Carlim limestone. Owing to its siliceous impurities it is rejected in quarrying for fluxing rock and in some quarries left standing as a projecting rib as illustrated here. Lowville limestone on left, Carlim limestone on right. Elk Run 1¼ miles southwest of Ironville. Looking northeast.

B. Lowville limestone with Rodman limestone on left and Lemont member of the Carlim limestone on the right beyond the telegraph station. Cut on the main line of the Pennsylvania Railroad just northwest of Union Furnace. Looking northwest.

LOWVILLE LIMESTONE

The Lowville limestone was named from Lowville, Lewis County, New York. It is a geographic name replacing the older name Birdseye limestone.

The Lowville parallels the Carlim in distribution.

It is exposed in the quarries at Union Furnace and on Elk Run (See Plates 6, 7B), and at Stover. It is the main quarry rock. At Union Furnace it is 307 feet thick, including at the bottom 42 feet of magnesian limestone.

So far as carefully examined in this area the Lowville is a dark limestone, fine-grained or compact and medium thick-bedded. At Union Furnace the Lemont member of the Carlim limestone is succeeded by about 40 feet of fine-grained rather thick-bedded dark limestone that weathers with the surface appearance of dolomite. This is probably the beds Nos. 12 and 13 of the table of analyses in the bulletin on the limestones of Pennsylvania by Miller[6]. The average of the two analyses of this bed, 42 feet thick, is 68.61 percent calcium carbonate, 20.9 percent magnesium carbonate, and 10.58 percent silica. It is uncertain whether this 42 feet in which no fossils have been found is of Chazy or Black River age. Above this intermediate horizon is about 40 feet of oolitic, fossiliferous, dark limestone with abundant ostracodes.. Near the top of this 40 feet *Tetradium cellulosum* and *Bathyurus superbus*? occur together in the same layer and the *Bathyurus* a little higher also. Some of the layers in this part of the formation contain small subangular pebbles of limestone. The rest of the Lowville up to the Rodman limestone is more or less fossiliferous dark limestone. A considerable part of the formation is of compact texture, tending to break with a conchoidal fracture. The greater part of the formation is a high-carbonate rock with a low percentage of insoluble matter. This rock is quarried for lime and preferably for fluxing rock in the Nittany Valley generally. In the quarry at Union Furnace there is a thickness of 220 feet that averages 93.12 percent calcium carbonate, 2.97 percent magnesium carbonate, and 3.03 percent silica, the total carbonate being practically 96 percent. The base of this pure rock is at the top of the magnesian rock 42 feet thick described above.

The Lowville is rather fossiliferous, but no thorough investigation of the fossils of this region has been made, so that a list that would be even approximately complete can not be given. A few such characteristic forms as *Cryptophragmus antiquatus* and *Tetradium cellulosum*, which are nowhere known to occur except in the Lowville or its partly equivalent Moccasin limestone or Bays sandstone of southwestern Virginia and eastern Tennessee, are known to be present. These fossils are sufficient to determine the age of the formation here described as Lowville. It is of interest that a trilobite identical with or very nearly the same as *Bathyurus superbus* Raymond occurs in association with *Tetradium cellulosum* in the lower part of the Lowville at Union Furnace. This trilobite was referred by Raymond to the

[6] Miller, Benjamin Leroy. Limestones of Pennsylvania: Pennsylvania Top. and Geol. Survey Bull. M20, p. 413, 1934.

Pamelia limestone of late Stones River age or to the immediately overlying Lowville limestone. Other geologists refer the Pamelia limestone to the Lowville also.

RODMAN LIMESTONE

The Rodman limestone is named from Rodman station on the Henrietta branch of the Pennsylvania Railroad about 1 mile north of Roaring Spring, Blair County.

This formation is persistent throughout the Tyrone quadrangle and is easily identified in all the quarries as it invariably marks the upper limit of quarrying. (Plate 8, A). It is 20 to 30 feet thick. Lithologically the Rodman is a very dark, fragmental, argillaceous limestone, largely made up of fragmental fossils, these constituents combining to give to the weathered rock a peculiar rough, dark gray surface which contrasts plainly with the smooth surface and light color of the weathered Lowville. The mass tends to become thin layered or to break up into small plates on weathering.

Fossils are plentiful in the Rodman. They include: *Aulopora? trentonensis*, a proliferous cyathophylloid coral suggestive of *Streptelasma divaricans*, *Carabocrinus* cf. *C. radiatus*, large crinoid stem plates, *Cleiocrinus?*' *Echinosphærites* sp., *Escharopora subrecta*, *Monotrypa magna*, *Prasopora simulatrix?*, *Rhinidictya trentonensis*, *Stictoporella angularis?*, *Pianodema subæquata*, *Rafinesquina minnesotensis*, *Rhynchotrema subtrigonale*, *Gonioceras anceps?*, *Plectoceras undata*, *Amphilichas* cf. *A. trentonensis*, *Bumastus trentonensis*, *Cryptolithus tesselatus?*, *Thaleops ovatus*. The fossils especially significant for correlation are *Echinosphærites* sp., *Gonioceras anceps*, and *Plectoceras undata*. The *Echinosphærites* indicates that the Rodman is to be correlated with the lower zone with that form in the Mercersburg-Chambersburg region, Pennsylvania, where it immediately overlies beds of Lowville age with *Tetradium cellulosum* and is thus in the same stratigraphic position as the Rodman in the Nittany Valley. The *Gonioceras* and *Plectoceras* may indicate equivalence with the Watertown limestone, which contains the same fossils and which immediately overlies the Lowville at its type region in New York.

UNCONFORMITY ?

CHAMBERSBURG LIMESTONE ABSENT ?

As originally defined by Ulrich[7] the Chambersburg limestone included at bottom the Lowville limestone, 150 to 190 feet thick, and next above the *Echinosphærites* bed, 65 feet thick. At present the application of the name Chambersburg in the Chambersburg region, Pennsylvania is apparently restricted to the 492 feet of limestone between the *Echinosphærites* bed and the base of the Martinsburg shale. The Chambersburg as thus restricted is regarded as of uppermost Black River age and is without representatives in the Nittany Valley, unless by the Rodman limestone.

[7] Stose, G. W. and Ulrich, E. O. U. S. Geol. Surv., Mercersburg—Chambersburg folio, field edition, pp. 58-59, 1910.

A. Nearly vertical wall of Rodman limestone generally marking the upper limit of quarrying in the Nittany Valley. Lowville limestone quarried out on right. Quarry on Elk Run about west of Ironville. Looking northeast.

B. Trenton limestone. Quarry at Union Furnace. Southeast limit of the Canoe Valley syncline, the axis of which is about 300 feet to left of beds shown. Looking northeast.

TRENTON LIMESTONE

The name Trenton is perhaps one of the most familiar to American geologists but the name has in many cases been misapplied both in a formational as well as in a group sense. The type locality is on West Canada Creek, Herkimer County, New York, where most of the formation is exposed in the gorge of the creek extending for 2½ miles above the village of Trenton Falls, from which it takes its name. In that vicinity the formation is limestone 350 to 500 feet thick with shaly partings. In central Pennsylvania it is intended to apply the name to limestone of the same general character and thickness as that at the type locality.

The Trenton crops out in belts ⅛ to ¼ of a mile wide along the east foot of Bald Eagle and of Brush Mountains, along the west foot of Lock and Tussey Mountains, and around the northeast end of the Canoe Valley syncline at Union Furnace. Good exposures may be seen at the quarry at Union Furnace (Plate 8, B) and on the road just southwest of the quarry at Stover. The Trenton is about 500 feet thick as measured along the Pennsylvania Railroad in the belt just west of Ironville and about a mile southeast of Tyrone, and it seems to be of comparable thickness elsewhere.

The rock is evenly thin-bedded or flaggy, black or dark, predominantly very fine-grained, compact limestone, the even thin layers being without noticeable shale partings and closely packed together. On weathering, the dark rock bleaches to a slight depth and produces thus an exterior thin gray film. Surfaces underlain by the formation are commonly littered with flat pieces of earthy gray rock that give indubitable evidence of the Trenton beneath.

The formation is not very fossiliferous, but a few diagnostic Trenton fossils have been found in this general region, such as *Dalmanella rogata, Dinorthis pectinella, Rhynchotrema increbescens, Ceraurus pleurexanthemus, Cryptolithus tessellatus,* and *Homalonotus* (*Brongniartia*) *trentonensis.* Except the *Homalonotus*, the species of this list are common and well known in the typical Trenton and attest the Trenton age of the limestone here described. The list could be considerably lengthened by including species not confined to the Trenton.

REEDSVILLE SHALE

The Trenton is succeeded by the Reedsville shale, named from Reedsville, Mifflin County, Pennsylvania. This formation crops out on the slopes toward the anticlinal axes of all the Tuscarora quartzite ridges—Bald Eagle, Brush, Lock, and Tussey Mountains. It is almost all cut out by the Water Street fault along the west slope of Tussey Mountain, south of Spruce Creek. The outcrop and upper limit of the Reedsville on the slopes are marked in many places by cleared land. At the base, just above the Trenton limestone, is a persistent bed 30 to 50 feet thick, of black calcareous shale or strongly argillaceous, fissile, black limestone containing graptolites. Next above is grayish-brown shale with thin layers of argillaceous or sandy limestone or of sandy clayey rocks, all of which resist weathering more strongly than the shale and show distinctly on weathered ex-

posures (see Plate 9, A). These limy and sandy layers increase in number and proportion toward the top so that there is no marked change to the overlying Oswego sandstone. The grayish-brown shale predominating in the lower half of the Reedsville commonly breaks down into small slivers because the shale is closely jointed or sheared perpendicular to the bedding through pressure involved in the folding of the region.

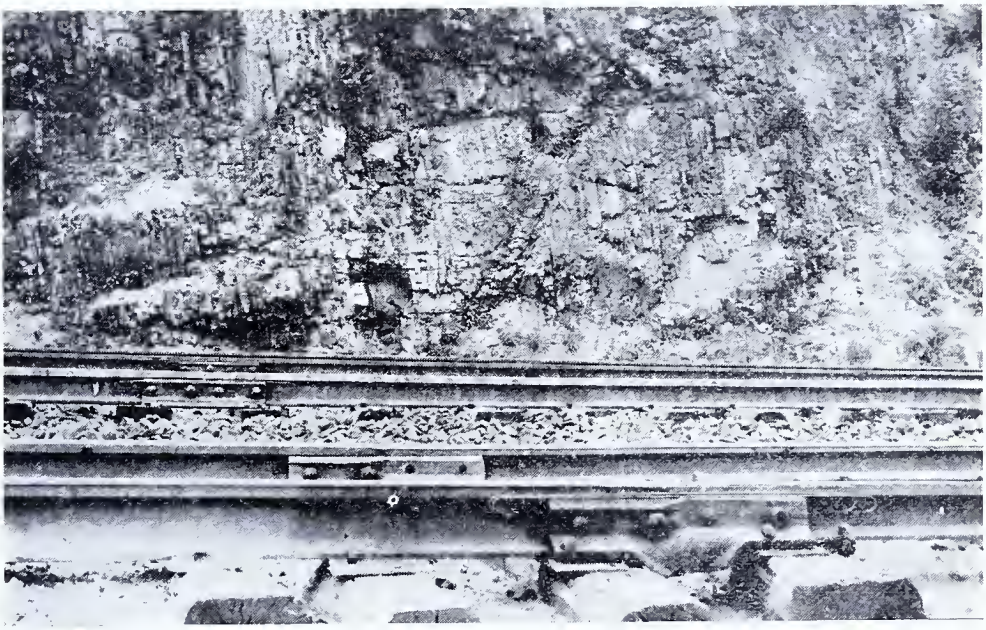
The thickness of the Reedsville is about 1,000 to 1,200 feet. It appears to be at least 1,150 feet thick along the Pennsylvania Railroad 1 mile southeast of Tyrone, but there are some undetermined factors that may modify that figure.

The shale of the formation does not yield many well preserved fossils, but some of the harder limy layers are crowded with such common fossils as *Rafinesquina* and *Sowerybella* (*Plectambonites*). The massive coarse siliceous limestone 40 feet or so thick at the top, just under the Oswego sandstone, contains many species of pelecypods and the very characteristic *Orthorhyncula linneyi*. A few of the more diagnostic species are the following: *Climacograptus* aff. *C. typicalis*, *Dicranograptus nicholsoni*?, *Diplograptus foliaceus* var. *vespertinus*, *Aspidopora newberryi*, *Hallopora sigillaroides*, *Dalmanella multisecta*, *Lingula nickelsi*, *Orthorhyncula linneyi*, *Plectorthis fissicosta*, *Strophomena hallie*, *Zygospira cincinnatiensis*, *Byssonichia radiata*, *Clidophorus* (sp)?. *Colpomya* (sp.)?, *Ctenodonta* (sp.)?, *Cymatonota* (sp.)?, *Lyrodesma poststriatum*, *Orthodesma* (sp.)?, *Pterinea demissa*, *Psilochoncha* cf. *C. inornata*, *Rhytimya* (sp.)?, *Whiteavesia* (sp.)?, *Cyrtolites ornatus*, *Sinuites cancellatus*, *Ceratopsis chambersi*, *Calymene meeki*, *C. granulosa*. The graptolites occur in the basal black shale. Most of the pelecypods and *Orthorhyncula* occur in the top 40 feet or *Othorhyncula* zone, and this assemblage persists to the latitude of Morristown, Tenn. Most of the fossils occur also in the Lorraine of New York and the Eden and Maysville of Ohio, so that the Reedsville is correlated with these formations. The basal graptolitiferous black shale probably corresponds to some part of the Utica shale of New York. The Trenton and Reedsville are substantially equivalent to the Martinsburg formation farther east.

OSWEGO SANDSTONE

The Oswego receives its name from Oswego, N. Y., the designation "gray sandstone of Oswego" having been given it by Vanuxem in 1842. It was named Oneida by the Second Geological Survey of Pennsylvania through mistaken identification with the Oneida of central New York and more recently has been called Bald Eagle sandstone by Grabau.

The Oswego crops out on the mountain slopes toward the anticlinal axes. Owing to its superior resistance to erosion, it makes a terrace half-way up the slopes, which is plainly marked by a series of flat-topped spurs separated by deep ravines resulting from the trenching of the terraces by transverse streams. These spurs are conspicuously displayed on the northwest slope of Brush Mountain southwest of Union Furnace and are rather conspicuous features on all the designated slopes except that of Bald Eagle Mountain.



A. Reedsville shale a short distance below top. Pennsylvania Railroad about 1 mile southeast of Tyrone. Looking southwest.

B. Northeast face of Tussey Mountain showing extensive areas of slide rock from the Tuscarora quartzite cropping out on the crest of the mountain. Looking northeast in the vicinity of Goodman, 10 miles southeast of Tyrone.

The best exposures of the formation are in Tyrone Gap, Water Street Gap, and in the quarry ¾ of a mile south of Water Street. The railroad tunnel about 1 mile southwest of Spruce Creek station is mainly in the Oswego.

The Oswego is generally medium thick-bedded, fine-grained, steely blue-gray or greenish-gray sandstone, some parts of which are characteristically speckled brown, presumably from the decomposition of iron pyrites. Many of the layers are finely cross laminated. Rarely a few quartz pebbles occur in the basal layers. There are occasional layers of green sandy shale and, as displayed in Tyrone Gap, an occasional thin layer of red shale.

The Oswego is 800 to 1,000 feet thick. It can hardly be less than 1,000 feet in Tyrone Gap.

As the Oswego sandstone is unfossiliferous, its age can not be determined from internal evidence. In New York fossils of lower Maysville (Fairview) age occur just below the Oswego, or even in what may be regarded as its basal layers, and the pelecypods occurring with *Orthorhyncula linneyi* just beneath the Oswego in central Pennsylvania are also lower Maysville, so that the beds just below the sandstone are the same age in New York and Pennsylvania. As Ulrich finds no evidence of a stratigraphic break in New York he regards the Oswego as representing the upper Maysville (McMillan) of the Cincinnati region and thus of Upper Ordovician age, and that correlation is accepted here upon Ulrich's authority.

JUNIATA FORMATION

Next above the Oswego in central Pennsylvania is a thick red formation named the Juniata from Juniata River by N. H. Darton in 1896. It is the red Medina of the Pennsylvania Second Geological Survey.

The formation occupies the slopes of the mountain ridges toward the anticlinal axes from the crest down to the inner edges of the flat-topped spurs made by the Oswego sandstone. The contact of the Juniata with the Tuscarora quartzite next above is generally on the crest of the ridges, but in the gaps the Juniata usually extends a short distance over the summits on to the opposite slope of the ridge from that occupied by the main body of the formation. A good example is on the road between Bald Eagle and Spring Mount, as can be seen by an inspection of the geologic map. The Juniata red beds have been traced into southwestern Virginia where they interfinger with the Sequatchie formation in which the writer has obtained *Drepanella richardsoni* and other fossils. These species show that the Sequatchie and hence the Juniata are equivalent to the Richmond group of southwestern Ohio. The red Queenston shale of western New York occupies a stratigraphic position similar to that of the Juniata of Pennsylvania, and in Ontario interfingers with marine beds containing diagnostic Richmond fossils. It is reasonably clear that the red Juniata shale and sandstone of central Pennsylvania is the southern extension of the red Queenston shale of New York; and that both these beds are an eastern deltaic facies of the marine Richmond beds of Ohio.

Early New York geologists included the Queenston or "Red Medina" in the Silurian system. On the basis of its faunas, the Richmond group has long been accepted as late Ordovician in age. When it was discovered that the Queenston and Juniata were equivalent to the Richmond, many geologists referred these formations to the Ordovician system, and this classification has been accepted by the United States Geological Survey. Ulrich believes that correlation of the Richmond with late Ordovician beds of England is not well assured and on the basis of a pre-Richmond unconformity and the long New York usage which preceded establishment of the Ordovician in England, believes that the base of the Richmond-Queenston beds is the most acceptable boundary between the Ordovician and Silurian systems in North America.

The outcrop of the Juniata high on the ridges is marked in many places by cleared lands with red soil and farms and apple orchards.

The rock of the Juniata is mainly fine-grained reddish sandstone and a little greenish-gray sandstone. Fine crossed lamination is common. Intercalcated in the sandstone are layers of red shale up to a few feet thick. Somewhere near the middle there seems to be a greater thickness of the comparatively soft shale, for in places, where the formation is cut transversely by water gaps, deep longitudinal ravines follow the middle of the outcrop a long distance back from the main streams. There is an especially good example of this on the southwest side of the Tyrone Gap.

No fossils have been found in the Juniata, and in Pennsylvania it is believed to be entirely destitute of organic remains.

The thickness of the Juniata is approximately 1,200 feet.

SILURIAN SYSTEM

By Frank M. Swartz

In the area of the Tyrone quadrangle, the Silurian system includes the following formations, listed in stratigraphic order:

	Feet
Keyser limestone	105
Tonoloway limestone	700
Wills Creek shale	500
Bloomsburg red beds	50
McKenzie formation	
Upper shale and limestone member	100
Rabble Run red bed member	50
Lower shale and limestone member	200
Clinton group	
Rochester shale	60
Keefer sandstone	20
Rose Hill shale	600
Castanea sandstone	40
Tuscarora sandstone	500

The thicknesses given are based on measurements obtained in the southeastern part of the quadrangle, where the total thickness of the system is about 3,000 feet. See Figure 3.

TUSCARORA SANDSTONE

The Tuscarora sandstone was named by Darton (1)* from Tuscarora Mountain, which is supported by this formation where it crops out along the northwestern boundaries of Perry and Franklin counties. The formation is about 400 to 500 feet thick in the Tyrone quadrangle, according to Butts.

The Tuscarora sandstone forms the core and summit of each of the high ridges, such as Tussey and Bald Eagle Mountains, that dominate the topography of the Tyrone quadrangle. It forms a great mantle of white boulders which are conspicuously displayed in rock streams or slides along the mountain slopes, as on Tussey Mountain just southeast of Water Street (see Plate 9B). Bedrock is well displayed in a quarry on the northwest slope of Short Mountain, 2 miles south of the village of Spruce Creek; also in a quarry on Tussey Mountain north of Little Juniata River, at the gap 1½ miles northwest of Barree. Ledges of the rock are also common along the ridge crests. The upper part of the Tuscarora is well exposed, together with overlying Castanea and Rose Hill beds, in a cut along the main line of the Pennsylvania Railroad about ½ mile north of Barree (see Plate 10). The beds in this cut are disturbed by a nearly horizontal fault, overthrust from the west. The section exposed here is described below.

Section of Castanea and upper part of Tuscarora sandstones

At railroad cut about ½ mile northwest of Barree, opposite watchman's house. Measured with assistance of F. M. Swain.

	Feet Bed	Feet Total
ROSE HILL SHALE		
Gray to greenish and some purplish argillaceous shale. The basal 13 feet are exposed along the track in the cut; higher beds are exposed on the bluff, and the greater part of the Rose Hill crops out along an abandoned curve southwest of the present tracks, between the cut and Barree.		
CASTANEA SANDSTONE		
Thick-bedded dark gray arenaceous shale or siltstone, with some thin layers of harder sandstone, above; thin-bedded, greenish gray, arenaceous shale and interbedded greenish gray sandstone, below. Top not well defined. These beds might well be included in the Rose Hill.	12	43
Thin-bedded, dark gray, fine-grained quartzitic sandstone, and some interbedded arenaceous shale.	4	31
Thick-bedded, dark red, fine-grained sandstone.†	2	27
Thin-bedded, greenish gray, arenaceous shale, and interbedded greenish gray to dark gray, fine-grained sandstone, in layers 1 to 6 inches thick. A bed of hard gray and purplish quartzitic sandstone 1½ to 2¼ feet below top.	22½	25
Thick-bedded, argillaceous greenish sandstone or siltstone, with small concretions which weather red.	2½	2½
TUSCARORA SANDSTONE		
Thick-bedded, hard, brownish-gray, fine-grained quartzitic sandstone.	4	132
Thin-bedded, greenish gray, and some whitish fine-grained quartzitic sandstone, and some interbedded dark gray arenaceous shale or siltstone; 2 feet of shale at top.	12	128

* Figures in parenthesis refer to Bibliography at the end of this chapter.

† All Clinton. Butts. See footnote [8].

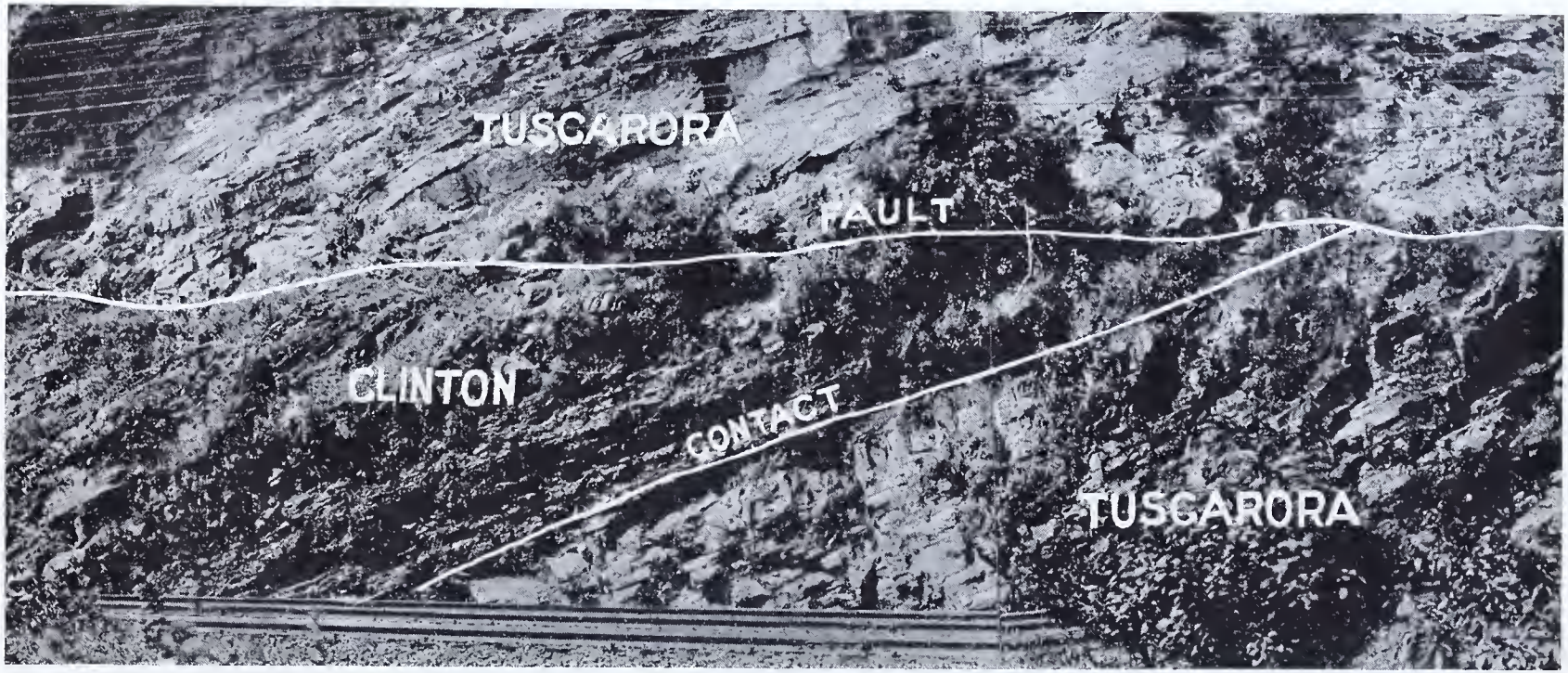
‡ This bed is Clinton and represents the block ore. Lower Clinton ostracods were collected from it at Marklesburg.—Butts.

Medium- to thick-bedded, dark greenish gray and some whitish fine-grained quartzitic sandstone, with partings of arenaceous shale, especially in the lower part.	24	116
Thick-bedded hard white to greenish fine-grained quartzitic sandstone. In part with small rusty pits, possibly left from weathering of iron sulphide grains.	25	92
Thin-bedded, dark gray, arenaceous shale or siltstone, and interbedded thin-bedded greenish and gray sandstone. A 6-inch bed of harder quartzitic sandstone, with numerous small rusty pits, 1 to 1½ feet above base.	3	67
Medium- to thick-bedded dark greenish gray sandstone; lower 8 feet with some interbedded arenaceous shale.	13	64
Thick-bedded, hard, white, fine-grained quartzitic sandstone, in part with numerous small rusty pits.	21	51
Thin-bedded, dark gray, arenaceous shale or siltstone. 3-inch bed of whitish sandstone at 1½ feet; 3-inch bed of argillaceous sandstone, with *Arthrophycus* on base, at 5 feet.	10	30
Thick-bedded hard white and greenish white quartzitic sandstone; in part with numerous small rusty pits. A 3-inch bed of arenaceous shale at 10½ feet. Upper 4 feet partly concealed. Large *Scolithus* tubes 8 to 10 feet above base.	20	20
Concealed for a long distance to the north. Lower Tuscarora and upper Juniata can be seen in old quarries on the slope of Tussey Mountain, northeast of the river. About ½ mile to the northwest of the cut, 260 feet of red arenaceous shale or siltstone and soft red sandstone, apparently a little below the middle of the Juniata formation, can be seen along the railroad fork leading to the southern of the two tunnels cut through the Oswego sandstone spur of Short Mountain.		

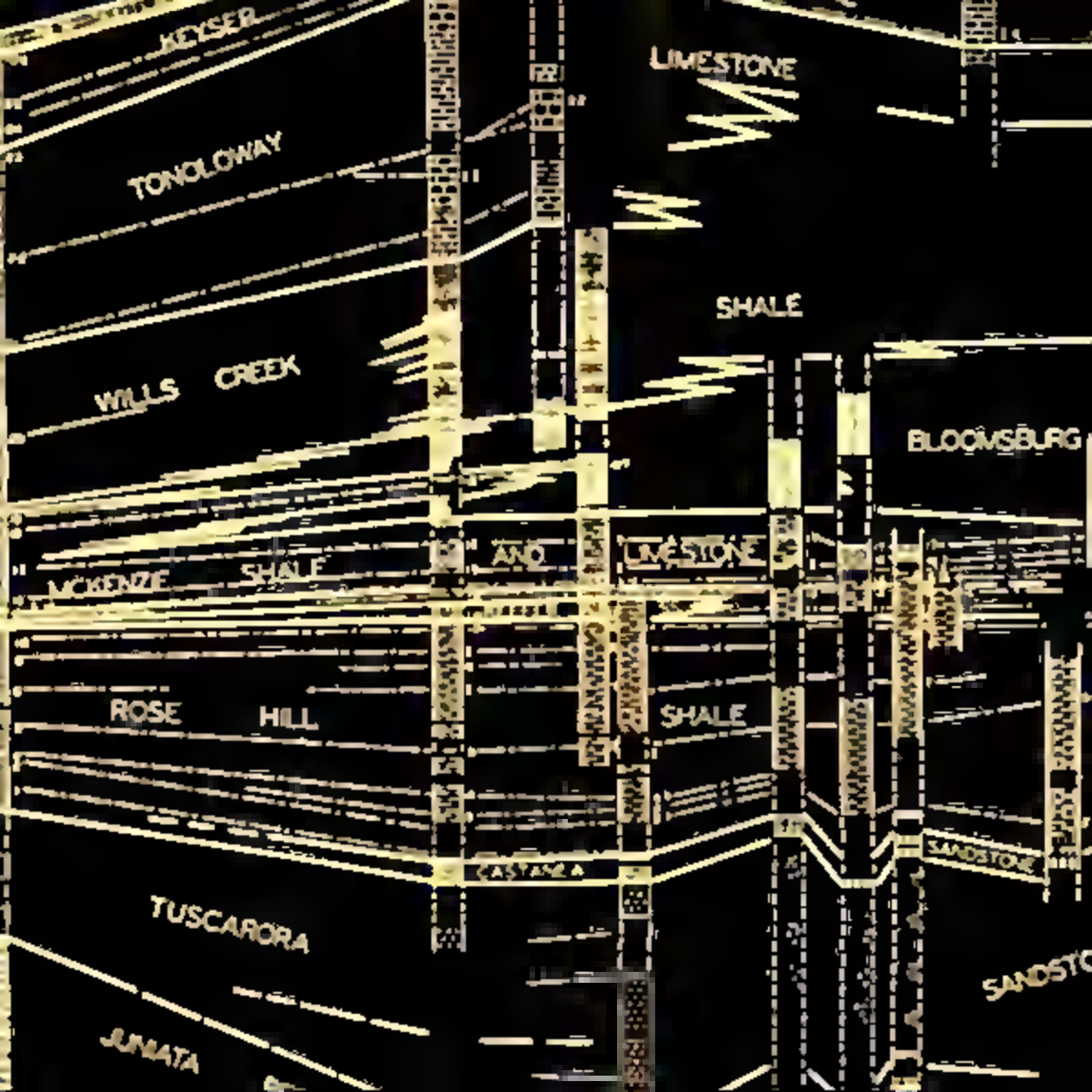
As can be seen in the above section and at other exposures, the Tuscarora formation is largely composed of gray to white sandstone, formed from exceptionally pure quartz sand. The rock is quartzitic, thin sections showing the original quartz grains cemented by silica overgrowths. The beds of dark gray shale or siltstone seen in the railroad cut are similar to beds in the Tuscarora section on Long Mountain, 10 miles north of Lewistown. In some quarries, as the one on the top of Lock Mountain, about ½ mile west of Point View station, such shale beds are represented by occasional layers of soft clay from a few inches to as much as 18 inches thick. The long-continued weathering to which the rocks of the ridge summits and slopes have been subjected, has considerably enhanced the apparent purity of the Tuscarora, both by disintegration of the shale layers and removal of the small content of iron sulphide (?).

The writer has not examined the contact between the Tuscarora and underlying Juniata formation in the area of the Tyrone quadrangle. North of Lewistown, about 22 miles east of the Tyrone quadrangle, the Tuscarora is about 750 feet thick. The lower 145 feet of gray to white sandstone are overlain by 115 feet of pink to reddish sandstone (20). It is possible that the latter beds correspond in age to the upper part of the Junita formation in the Tyrone quadrangle.* Some red shale of Juniata type is also interbedded with white sandstones at the base of the Tuscarora at McKee Gap, 12 miles southwest of the Tyrone quadrangle. As currently drawn, the boundary between the Tuscarora and Juniata formations is not always well defined, and may vary considerably in age from place to place.

* It is just as probable that a few layers of sandstone are interbedded with red shale in the top of the Juniata.—Butts.



Horizontal thrust fault opposite watchman's house on main line of Pennsylvania Railroad about ½ mile northwest of Barree. Thrust from northwest pushed Tuscarora quartzite over Clinton beds. This view, looking southwest, shows only part of the exposed fault.


KEYSER
LIMESTONE
TONOLOWAY
SHALE
WILLS CREEK
BLOOMSBURG
AND
LIMESTONE
MCKENZIE
SHALE
ROSE HILL
SHALE
CASTANEA
SANDSTONE
TUSCARORA
SANDSTO
JUNIATA

The only fossils observed in the Tuscarora are *Scolithus* tubes, which abound in some layers; *Arthrophycus alleghenensis*, and *Dædalus archimedes* (Plate 11A). *The Arthrophycus* and *Dædalus* occur in the upper part of the formation.

The Tuscarora sandstone continues into eastern Pennsylvania, where it overlaps the Juniata, becomes coarser, and combines with sand and pebble beds of Clinton age to form the Shawangunk conglomerate (15, 16). It extends southward through Maryland, and in southwestern Virginia and eastern Tennessee is known as Clinch sandstone (17). The Albion (Medina) group of western New York, or at least the Whirlpool sandstone member, appears to represent part of the Tuscarora. (See Figure 3.) The Brassfield limestone of the Ohio Valley region is believed to be a marine equivalent.

CLINTON GROUP

The Clinton group, well known for its beds of iron ore, was named by Vanuxem from the town of Clinton, Oneida County, New York (27). In the Tyrone quadrangle, this group includes the following formations, listed in ascending order: Rose Hill shale, Keefer sandstone, and Rochester shale. The Castanea sandstone is in this area intimately related to the Clinton group, and has been mapped as part of the Clinton in the Areal Geology map. At other localities, where the Castanea contains less shale, it could well be regarded as a member of the Tuscarora sandstone.

In the Tyrone quadrangle, the Clinton group has a total thickness of about 700 feet. The beds crop out in narrow belts on the up-dip slopes of the ridges made by the Tuscarora sandstone.

CASTANEA SANDSTONE[8]

Near Castanea, a suburb of Lock Haven, about 40 miles northeast of the Tyrone quadrangle, the Tuscarora sandstone is overlain by 75 feet of red and some green sandstone and shale, named Castanea sandstone by the writer (20). The 43 feet of arenaceous shale and interbedded hard gray and some red sandstone, lying above the Tuscarora in the section ½ mile northwest of Barree, are believed to be the southern continuation of this formation.

Because of their argillaceous character and thinness, the Castanea beds have been mapped as a basal member of the Clinton group in the Barree region. Toward Mount Union (2), Williamsport, and Danville, Pennsylvania, the beds become more sandy, are intimately related to the Tuscarora sandstone, and at Danville were included in that formation by C. K. Swartz and the writer in 1931 (16). Because of these lateral changes, treatment of the Castanea beds as a member of either the Clinton group or Tuscarora sandstone is not wholly satisfactory; actually, they could be regarded at different places as forming a member of each of these rock bodies.

[8] In the Marklesburg region there is a persistent sandstone about 25 feet thick above the block ore bed that can reasonably be separated out as a member of the Clinton and has been so separated and mapped in the Huntingdon quadrangle. No such sandstone is present in the Barree section but it is probably represented by the 12 feet of shale with thin sandstone at top as shown in the accompanying section. This entire section is Clinton as shown by the block ore and by the ostracods obtained from the ore bed at Marklesburg. I do not think the beds at Barree are entitled to rank as a member of the Clinton even.—Butts.

The red sandstone of the Castanea beds is persistent through the Tyrone area, and represents the "block ore" of previous reports. Much debris from it is scattered over the surface at the south end of Round Top and also along its southeast flank. Large masses occur on the southeast slope of Leading Ridge. A mile or so northwest of Marklesburg, 15 miles south of Barree, a lens of "flax seed ore" at about this horizon was mined out years ago. No ore is known to occur at this horizon in the Tyrone quadrangle.

At Marklesburg, Ulrich and Bassler report *Anoplotheca hemisphcrica*, and *Zygobolba erecta* and other ostracoda from the red sandstone (24). The *Z. erecta* fauna has been found in these sandstones near Hollidaysburg, Pennsylvania, but is not known at any other localities.

The red sandstones of the Castanea become thicker toward Lock Haven and Williamsport. Similar red beds are reported above white sandstone, evidently representing the Tuscarora and Whirlpool formations, in deep wells in northern Pennsylvania and southwestern New York (23). The writer has accordingly suggested that the Castanea sandstone is probably continuous with the red Grimsby beds which form a large part of the early Silurian Albion (or Medina, restricted) group of western New York (20). The unconformity that has been reported at the base of the Albion at Rochester, New York (24), where red Albion beds rest directly on red Queenston, may represent the emergence of that region during at least part of Tuscarora time. The limits of both the Juniata-Queenston and Castanea-Albion red beds may of course vary considerably in age within these areas.[9]

The red Castenea beds of the Lock Haven-Williamsport area (see Figure 3) should not be confused with the purplish iron-rich sandstones intercalated in higher Rose Hill horizons toward Millerstown and Swatara Gap, Pennsylvania, as well as in parts of Maryland, West Virginia, and Virginia. They lie at a lower level, below the early Clinton *Zygobolba anticostiensis* zone. Typically, the red sandstones are red rather than purplish; frequently they are pierced by numerous *Scolithus* tubes. The *Z. erecta* zone ostracoda found near Marklesburg and Hollidaysburg (25) occur presumably in extensions of the Castanea beds; they were regarded by Ulrich as related to, though older than the known ostracode faunas of the Clinton of New York and Maryland. If, as seems very plausible, the Castanea sandstone is continuous with the red beds found just above the Tuscarora-Whirlpool sandstones in deep wells in northwestern Pennsylvania, it has a considerable geographic extent.

ROSE HILL SHALE[10]

The Rose Hill shale was named by C. K. Swartz from exposures on Rose Hill, at Cumberland, Maryland (10). In the Tyrone quadrangle, the Rose Hill is formed almost wholly of thin-bedded, olive-green,

[9] These peculiar red sandstone layers increase to several beds intercalated in ordinary Clinton shale on the James River, Va. They occur in the lower half of the Clinton and this part of the Clinton was named the Cacapon sandstone by Darton. The red sandstone is very characteristic. Nothing like it occurs in any other formation in the valley.—Butts.

[10] As the Rose Hill makes up 90 percent of the Clinton, I think it should not be regarded either as a member or a separate formation. As I see it, there is a Clinton formation with a Rochester shale and a Keefer sandstone member at the top and locally a Castanea sandstone member a little above the bottom.—Butts.

argillaceous shale. There are a few 1 to 3- or 4-inch layers of calcareous sandstone, and, near the top, some 2- to 6-inch beds of fossiliferous limestone. The thickness of the Rose Hill has not been carefully determined, but is about 600 to 650 feet. Its best exposure in the quadrangle is seen just north of Barree, along an abandoned curve of the Pennsylvania Railroad, southwest of the present tracks. The formation is generally covered by debris from the adjacent Tuscarora sandstone.

The uppermost Rose Hill beds are well exposed, together with overlying Keefer sandstone, in the west limb of the Leading Ridge anticline, about 1 mile east of Barree. The following section has been measured at this locality.

Section of Keefer sandstone and upper part of Rose Hill shale.

On north side of Little Juniata River, along highway to Petersburg about 1 mile east of Barree, Pennsylvania. Measured with the assistance of R. R. Rosencranz and C. J. Campbell.

	Feet Bed	Total
ROCHESTER SHALE		
Thin-bedded gray shale and some interbedded thin layers of limestone.		
KEEFER SANDSTONE		
Thick-bedded, hard, somewhat calcareous sandstone.	10	22
Thick-bedded arenaceous limestone, grading into calcareous argillaceous sandstone and siltstone.[11] More arenaceous layers weather in relief, forming ridges parallel to bedding. Lower 3 feet more shaly. At 5 to 9 feet above base: *Stropheodonta* sp. (c), *Whitfieldella intermedia* (c), *Pterinea emacerata* (c), *Diaphorastoma niagarensis* (c), *Homalonotus delphinocephalus* (c), *Dalmanites limulurus* (c).	12	12
These beds have been placed with the Keefer sandstone because of the disappearance of the distinctive ostracoda and brachiopoda which are so characteristic of the uppermost Rose Hill. See discussion of Keefer sandstone. (c), common.		
ROSE HILL SHALE		
Hard, somewhat fossiliferous, hematitic limestone, with 2- to 4-inch layer of green shale below middle. (Marklesburg iron ore). Cup corals (c), *Anoplotheca sulcata* (c).	2	30
Thin-bedded, greenish, argillaceous shale, weathering into rather irregular fragments; some 2- to 6-inch lenticular beds of very fossiliferous limestone, chiefly in the middle part. The limestone layers are largely composed of fossil shells, embedded in greenish and pinkish argillaceous matrix. The limestone beds contain *Atrypa reticularis, Anoplotheca sulcata, Mastigobolbina typus, M. arguta, Plethobolbina typicalis,* and other species of the *M. typus* zone	28	28
Concealed.		

The 2-foot bed of hematitic limestone or iron ore at the top of the Rose Hill is locally named the "front vein." Butts has renamed it the Marklesburg ore in the Hollidaysburg-Huntingdon folio (in press). It has been dug to some extent around the north end of Bunker Hill north of Barree, as shown by numbers of old pits. Its quality as an ore in the Tyrone quadrangle is not known.

[11] I question whether this should be included in the Keefer. It belongs with the beds below, (Rose Hill).—Butts.

The Rose Hill shale contains a large fauna. Among the non-ostracoda, the brachiopod *Anoplotheca hemispheria* is common in the lower and middle parts, but is replaced near the top by *A. sulcata* with weaker ribs. *Chonetes novascoticus* and *Liocalymene clintoni* occur in both the middle and upper parts of the formation; *Paleocyclus rotuloides, Sowerbyella transversalis,* and *Chonetes cornutus* are found in the upper part only.

The Rose Hill is characterized especially by diagnostic ostracoda, which have been recorded from numerous localities in the Appalachian region. The studies of Ulrich and Bassler have established the following zones, listed in stratigraphic order (25):

Mastigobolbina typus zone
Bonnemaia rudis zone
Zygosella postica zone
Mastigobolbina lata zone
Zygobolbina emaciata zone
Zygobolba decora zone
Zygobolba anticostiensis zone
(*Zygobolba erecta* zone)

These zones have not been worked out within the area of the Tyrone quadrangle, although a characteristic *Mastigobolbina typus* zone fauna occurs in the 30 feet of upper Rose Hill exposed below the Keefer sandstone in the section 1 mile east of Barree. As previously stated, the typical *Zygobolba erecta* fauna was obtained in red sandstones presumably belonging to the Castanea formation near Marklesburg, 15 miles south of Barree. In the section at that locality measured by Butts, the fauna occurs 58 feet above the base of these sandstone and shale beds, reported to be 99 feet thick. The overlying Rose Hill shales are 615 feet thick, with the Marklesburg ore at the top. The *Mastigobolbina typus* zone is recognized by Ulrich and Bassler in the 45 feet of shale exposed below the Keefer sandstone at Lakemont, between Altoona and Hollidaysburg, 8 miles southwest of the Tyrone quadrangle. They also reported the *Zygobolba decora* and *Z. erecta* zones from beds near the base of the Rose Hill near Hollidaysburg, but exact stratigraphic positions were not determined because of poor exposures.

The Rose Hill shale and other Silurian formations are finely exposed on the north side of the Juniata River opposite Mount Union, Pennsylvania, 10 miles southeast of the Tyrone quadrangle. At this locality, the Rose Hill is 725 feet thick, and, with the exception of the lower 115 feet, is mostly exposed. The following ostracode zones have been recognized by the writer in the Mount Union section (20):

Mastigobolbina typus zone, with *Illaenus ioxus* subzone in upper 5 feet
Bonnemaia rudis zone
Mastigobolbina modestus zone
Mastigobolbina lata zone
Zygobolbina emaciata zone
Zygobolba bimuralis, Mastigobolbina (?) retifera zone

A. Boulder of Tuscarora quartzite with *Dædalus archimedes* and close view of the slide rock mantling so much of the mountain faces. West slope of Bald Eagle Mountain above water tank of paper mill at Tyrone.

B. Sequence of Helderberg (New Scotland) limestone on left and Shriver sandstone on right. North base of small northwest knob in north environs of Tyrone. Looking south.

A few specimens referable to *Zygobolba decora* occur in the *Z. bimuralis* zone, but the other ostracoda indicate that this is not the *Z. decora* zone proper. The lower 115 feet of the Rose Hill, concealed in the Mount Union section, may well contain the *Zygobolba decora* and *Z. anticostiensis* zones. The Rose Hill is underlain by Castanea sandstone, 58 feet thick, including 16 feet of dark red sandstone, and less than 12 feet of shale. Except for numerous *Scolithus* tubes, no fossils were observed in the Castanea at Mount Union.

From the above observations, it is clear that most of the Rose Hill ostracode zones occur in the general Tyrone region, and presumably are present within the Tyrone quadrangle. These zones show that the Rose Hill in central Pennsylvania closely parallels the type Rose Hill at Cumberland, Maryland, where Ulrich and Bassler have reported the *Zygobolba anticostiensis*, *Zygobolbina emaciata*, *Mastigobolbina lata*, *Bonnemaia rudis*, and *Mastigobolbina typus* zones.

In New York, Ulrich and Bassler (25) have found the *Zygobolba anticostiensis* zone in the "Bear Creek shale," about 40 to 60 feet above the base of the Clinton group at Rochester. The *Z. decora* zone occurs in the typical Sodus shale of the Clinton at Alton. The *Mastigobolbina lata* zone occurs in the middle part of the Clinton group in Oneida County near Clinton. The *M. typus* zone is found 65 to 70 feet below the top of the Clinton group at Clinton.

The type *Zygobolba anticostiensis* fauna occurs in the upper 100 feet of the Gun River formation in the Island of Anticosti. The type *Z. decora* fauna is found about 600 feet higher, in the overlying Jupiter River formation of that area.

KEEFER SANDSTONE

The Keefer sandstone was named by Stose from Keefer Mountain, in the southwest corner of Franklin County, Pennsylvania (8). In the Tyrone quadrangle, this sandstone is thin but persistent through the area southeast of Tussey Mountain, where it forms a ridge or series of knobby spurs near the edge of the belts of Clinton outcrop. The knobby spurs are especially conspicuous south of Alfarata along a line running slightly west of south. About 1 mile southeast of Leading Ridge the outcrop of the Keefer is also marked by a line of rather prominent ridges.

The Keefer sandstone is well exposed in the section north of Little Juniata River and about 1 mile east of Barree, as hitherto described. It is also seen in the railroad cut 1,500 feet southeast of Barree. At these localities the Keefer is about 20 feet thick. The upper half is interbedded limy sandstone and greenish sandy shale. The lower half is less resistant, and varies from arenaceous impure limestone to calcareous and argillaceous sandstone and some arenaceous shale. The lower beds contain a considerable fauna, representing the *Schuchertella subplana* zone, which the writer has studied more extensively in sections near Mount Union and Lewistown, about 10 and 22 miles, respectively, east of the Tyrone quadrangle (20). Of the 17 species found in the *Schuchertella subplana* zone at these localities, 14 occur in the Rochester shale and Irondequoit limestone beds of western New York, and indicated close equivalence to those beds.

A very pronounced faunal change occurs in passing from the Rose Hill shale into the Keefer sandstone in the Barree, Mount Union, and Lewistown areas. *Chonetes novascoticus*, *Anoplotheca sulcata*, and *Liocalymene clintoni*, which are abundant in the upper Rose Hill, abruptly disappear at the top of that formation; while large and typical *Schuchertella subplana* first appears in the lower Keefer, as do *Whitfieldella* aff. *W. intermedia*, *Eospirifer niagarensis*, and *Homalonotus delphinocephalus*. The change is also marked in the case of the ostracoda. Thus species of the genera *Mastigobolbina*, *Plethobolbina*, *Zygosella*, and *Bonnemaia* are abundant to the top of the Rose Hill; but none of those genera is known in the Keefer, where ostracoda are rare, or in the overlying Rochester shale, where ostracoda of different genera and species are abundant. The faunal change from the Rose Hill to the *Schuchertella subplana* zone of the Keefer may be due in part to ecologic relationships; it probably also involves a break in sedimentation.

Recent work by the writer shows that the Keefer formation is absent as a sandstone along the northern flank of Bald Eagle Mountain near Howard, Lock Haven, and Williamsport, along a stretch about 20 to 70 miles northeast of the Tyrone quadrangle (see Figure 3). It is represented, however, by shale beds which contain the fauna of the *Schuchertella subplana* zone. It is not yet clear whether the Keefer has also changed to shale along the flank of this mountain in the northwestern part of the Tyrone quadrangle. At Lakemont, about 8 miles southwest of the Tyrone quadrangle, the Keefer sandstone is 15 feet thick, and is formed of impure arenaceous limestone, calcareous sandstone, and some interbedded shale (21).[11]

ROCHESTER SHALE

Shales below the Lockport dolomite of western New York were named Rochester shale by Hall in 1839 (2), although he and others subsequently used the term Niagara shale. Clarke and Schuchert revived Hall's earlier term in 1899. Until 1911, these shales were considered younger than the Clinton shale, named from the town of that name about 110 miles east of Rochester. In 1911 and later Ulrich presented evidence that the Rochester is represented in the upper part of the type Clinton section (25, 24). Subsequently, the United States Geological Survey has included the Rochester shale in the Clinton group. Nevertheless, some writers believe it would be better to amend the name, Clinton, by removal of the Rochester beds. The marked faunal change at the top of the Rose Hill shale favors this procedure, as applied to Pennsylvania.

Shales similar in character to the type Rochester and containing numerous Rochester fossils occur above the Keefer sandstone in Maryland and central Pennsylvania, and have been termed Rochester shale since 1923 (10). In spite of the abundance of Rochester species, these shales are especially characterized by *Drepanellina clarki*, a large ostracode unknown in New York. Consequently, they have been called the *Drepanellina clarki* zone by Ulrich and Bassler (25).

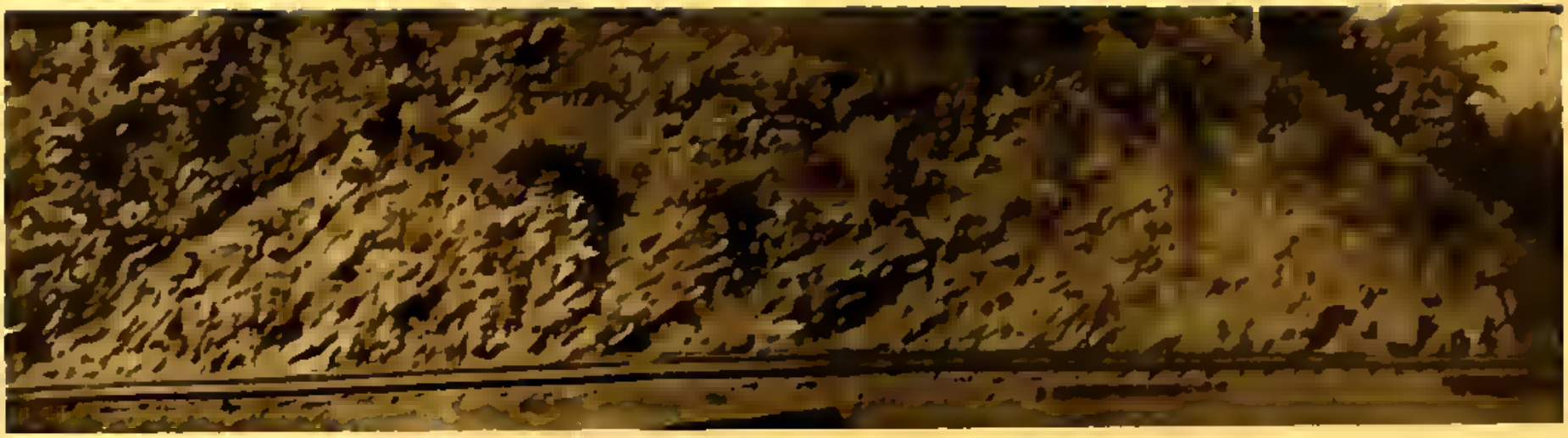
[11] In the Hollidaysburg region the Keefer is not present as a sandstone but seems to be represented by a rather massive calcareo-arenaceous rock weathering rusty. The same is true in the Monterey, region, Va.—Butts. The Keefer beds are, it is true, more calcareous and argillaceous at Lakemont; they form, however, a definite recognizable body of rock, differing from the overlying and underlying shales. For description, see 21, p. 1178.—F. M. S.

The Rochester shale or *Drepanellina clarki* zone is finely exposed in a cut along the Pennsylvania Railroad about 1,500 feet southeast of Barree (Plate 12, A). The section seen here is described below:

Section of Rochester-McKenzie beds

In cut along Pennsylvania Railroad, 1,500 feet southeast of Barree station. Measured with assistance of F. M. Swain. a, abundant; aa, very abundant; c, common; r, rare.

	Feet Bed	Total
McKENZIE FORMATION		
LOWER SHALE AND LIMESTONE MEMBER		
Concealed to east of cut.		
Gray calcareous shale and some thin-bedded, dark gray, finely crystalline limestone. At 175 feet: *Homeospira marylandica* (r), *Kloedenia normalis* (c), *Kloedenella intermedia* (a), *K. nitida* (c), *Eukloedenella sulcifrons* (c), *Dizygopleura brevisulcata* (r). This fauna represents the KLOEDENELLA NITIDA ZONE. At 145 feet: *Eukloedenella sulcifrons* profuse.	50	185
Medium- to thick-bedded, mostly dense, dark gray limestone, and some interbedded dark gray calcareous shale. Occasional lenses of flat pebble limestone conglomerate in basal foot and at higher horizons. Bed with peculiarly rough weathered surface 18 to 20½ feet above base of this unit. In part, beds are much crumpled. These are the typical dense dark gray limestones of the lower McKenzie. At 45 feet, in crystalline matrix around dense barren limestone pebbles: *Reticularia bicostata* (a), *Beyrichia moodeyi* (r), *Kloedenella intermedia* (aa). This fauna represents the BEYRICHIA MOODEYI ZONE. At 18 feet: *Whitfieldella marylandica* (aa), *Kloedenia ventralis* (a), *Kloedenella immatura* (c), *Dizygopleura conjugata* (c). This is the highest occurrence of the WHITFIELDELLA MARLANDICA-KLOEDENIA VENTRALIS ZONE coquinas. With careful search, however, recurrent *K. ventralis* should be found in the basal part of the *Beyrichia moodeyi* zone.	120	135
Thin- to medium-bedded, dark gray, somewhat arenaceous limestone, and interbedded dark gray shale, 3½ feet, above; thin-bedded dark gray calcareous shale, 4 feet, below. These beds form the main part of the WHITFIELDELLA MARYLANDICA-KLOEDENIA VENTRALIS ZONE. There are thin limestones virtually composed of *W. marylandica* at 10, 14, and 14½ feet. Other species were not obtained at 10 feet, but at 14 feet are: *W. marylandica* (aa), *Kloedenia ventralis* (a), *Kloedenella immatura* (a).	7	15
Thin-bedded gray calcareous shale, and much interbedded dark gray, finely crystalline, fossiliferous limestone in layers 1 to 6 inches thick. Some limestone layers are arenaceous and relatively barren. This is the SCHUCHERTELLA ELEGANS ZONE. It is separated from the underlying beds on the basis of change in fauna. However, because of the similarity in lithology, and important species derived from earlier beds as shown by the writer in previous papers, this zone might well be referred to the Rochester shale. (Numbers after fossil names denote distance in feet above base of formation.) *Pholidops squamiformis* (r) 2, (r) 6; *"Dalmanella"* sp. (c) 1; *Schuchertella elegans* (c) 1, (a) 2, (aa) 6; *Reticularia bicostata* (a) 1; *Whitfieldella marylandica* (c) 1, (a) 6; *Tentaculites* sp. (a) 6; *Paræchmina postica* (aa) 1, (aa) 2, (r) 6; *Kloedenella cornuta* and var. *prænuntia* (a) 1, (a) 2, (r) 6; *Dizygopleura symmetrica* (c) 1, (c) 2.	8	8
CLINTON GROUP		
ROCHESTER SHALE		
Thin-bedded to fissile gray shale weathering greenish; some interbedded 1- to 6-inch layers of gray crystalline fossiliferous limestone, and		



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occasional 1- to 3-inch layers of gray calcareous sandstone or arenaceous limestone. The limestone layers are increasingly numerous in the upper 14 feet; there are 6-inch layers at 3½ and 37 feet, and several 1- to 6-inch layers at 27 to 29 feet. This is the DREPANELLINA CLARKI ZONE, as restricted by the writer in central Pennsylvania. *Stropheodonta proutyi* (with the punctate shell structure not seen in *Schuchertella elegans*), *Camarotœchia neglecta,* and *Drepanellina clarki* are quickly found in almost every one of the fossiliferous limestones. Fragments of *Dalmanites limulurus* and *Homalonotus delphinocephalus* or var. *lobatus* are common. The top of the zone is commonly marked by the abrupt disappearance of *S. proutyi* and *D. clarki* (although *D. clarki* continues into the two next overlying zones at a section along the Western Maryland Railroad, about 10 miles southwest of Hancock, Maryland). *Homalonotus delphinocephalus* and var. *lobatus* also disappear; *Camarotœchia neglecta* and cf. *Dalmanites limulurus* occur at some places in the next overlying *S. elegans* zone, but are rare or absent in those beds at this locality. In this section, however, *Whitfieldella marylandica* appears in considerable abundance in the upper foot of the *D. clarki* zone. Fossils identified as follows: *Cornulites* sp. (r) 58; *Pholidops squamiformis* (r) 55, (c) 58; *"Dalmanella"* sp. (r) 55, (c) 58; *Stropheodonta proutyi* and var. (a) 21, (aa) 31, (c) 55, (a) 58; *Schuchertella subplana* (r) 21; *Camarotœchia neglecta* (c) 31, (c) 58; *Atrypa reticularis* (a) 31; *Whitfieldella marylandica* (a) 58; *W.* sp. (c) 31; *Tentaculites* sp. (r) 58; *Dalmanites limulurus* (r) 31; *Homalonotus delphinocephalus* or var. *lobatus* (r) 58; *Paræchmina spinosa* (c) 31; *P. postica* (c) 55, (a) 58; *Beyrichia veronica* var., frill narrow, female granulose, (r) 58; *Drepanellina clarki* (a) 21, (a) 31, (a) 55, (a) 58; *Kloedenella cornuta* var. *prænuntia* (r) 55, (a) 58; 1 specimen *K. cornuta* (58); *Dizygopleura symmetrica* (c) 55, (a) 58; *Octonaria cranei* (r) 21. 58 58

KEEFER SANDSTONE

Thick-bedded hard sandstone above, grading below into fossiliferous arenaceous limestone and calcareous, more or less argillaceous sandstone. Some hematitic limestone near base, possibly representing Marklesburg ore of uppermost Rose Hill. These beds are disturbed by faulting, so that exact thickness is somewhat uncertain. 5 to 6 feet: SCHUCHERTELLA SUBPLANA ZONE: *S. subplana, Whitfieldella* aff. *W. intermedia, Atrypa reticularis.* 18 18

Concealed to northwest.

The fauna of the *Drepanellina clarki* zone of the above section is characteristic of the Rochester shale as recognized in central Pennsylvania. The species *Dalmanites limulurus, Homalonotus delphinocephalus, Paræchmina spinosa,* and *Dizygopleura symmetrica* are diagnostic of the Rochester shale in western New York. *Stropheodonta proutyi, Drepanellina clarki,* and *Paræchmina postica,* though abundant here, are unknown in the New York Rochester, and suggest a slight difference in age.

McKENZIE FORMATION

The McKenzie formation was first described by Stose in the Pawpaw-Hancock folio in 1912 (8). The name is based, however, on exposures near McKenzie station, near Pinto, Maryland, described by W. F. Prouty and C. K. Swartz in 1923 (4). The McKenzie formation is persistent in central Pennsylvania, and occupies a belt of outcrop adjoining that of the Rochester shale of the Clinton group.

The McKenzie formation is about 350 feet thick near Barree, and is there divisible into three members, with several characteristic faunal zones. These are as follows:

Upper shale and limestone member, 100 feet, with *Kloedenella gibberosa* zone
Rabble Run red bed member, 50 feet
Lower shale and limestone member, 200 feet, with
- *Kloedenella nitida* zone
- *Beyrichia moodeyi* zone
- Barren zone
- *Whitfieldella marylandica-Kloedenia ventralis* zone
- *Schuchertella elegans* zone (Rochester?)

The lower member contains so much limestone that its presence, in the absence of exposures, can usually be recognized by limestone debris scattered over the surface. The fragments are in part dense and barren, in part crowded with valves of characteristic small ostracoda. The upper member is more likely to be confused with the Wills Creek. Without good exposures it is also difficult to separate the Rabble Run red bed member from the Bloomsburg red shale. At the time the quadrangle was mapped, the general occurrence of middle McKenzie red beds in south-central Pennsylvania had not been recognized. For these reasons, the Rabble Run and upper McKenzie have been included with the Bloomsburg and Wills Creek, and mapped as a unit in the Areal Geology map.

The lower member of the McKenzie is largely exposed in the railroad cut a quarter of a mile south of Barree station, as previously described. The following additional sections illustrate more fully the stratigraphy of the McKenzie formation in the Barree area.

Section of Lower McKenzie and Rochester in west limb of Leading Ridge anticline

On north side of Little Juniata River along highway to Petersburg, about 0.8 mile east of Barree, Pennsylvania. Measured with assistance of R. R. Rosencranz and C. J. Campbell.

McKENZIE FORMATION

RABBLE RUN RED BED MEMBER

Feet
Bed Total

Dark red shale, seen north of highway on east side of low hill near axis of syncline between Leading Ridge and Round Top Mountain anticlines. Thickness not determined; base uncertain.

LOWER SHALE AND LIMESTONE MEMBER

Mostly concealed. A traverse was run from exposures of the Lower McKenzie along the highway to the red bed as follows (bearings magnetic): concealed along highway, traverse N26°W to 100 feet; concealed across field, traverse N5°E to 280 feet; splintery shale, apparent dip 30°SE, exposed at northeast corner of a barn, traverse N5°E to 310 feet; concealed, traverse N37°W to 410 feet; gray shale and some dark limestone, exposed along lane 130 feet north of highway, strike and dip N51°E, 45°NW, traverse N28°W to 430 feet; concealed across small run to red soil on east slope of hill, traverse N28°W to 520 feet. Because of the limited exposures and the minor folding indicated by the southeast dip at 300 feet of traverse, no very satisfactory calculation of thickness of the lower member of the McKenzie is possible

here. However, a thickness of about 200 to not over 250 feet for the member seems probable. 185 feet of this member are exposed in the railroad cut southeast of Barree, in the section previously described.

Medium- to thick-bedded dark gray dense limestone, with thin interbedded layers and partings of dark gray shale. Prominent 3-foot bed of limestone at 20 to 23 feet above base; prominent 1½-foot bed of limestone at base. There are occasional lenses of flat pebble limestone conglomerate. These are typical lower McKenzie limestones. 55 71

Medium-bedded, finely crystalline, somewhat arenaceous limestone and interbedded shale, 3 feet, above; thin-bedded dark gray shale, 4 feet, below. Thin limestones at the middle of the 4-foot shale are crowded with *Whitfieldellas*. This is the main part of the WHITFIELDELLA MARYLANDICA-KLOEDENIA VENTRALIS ZONE; although the first of these species also occurs in underlying beds, and both range into overlying strata. 7 16

Thin-bedded, gray, finely crystalline, fossiliferous limestone, and interbedded dark gray shale. Limestones are in part somewhat arenaceous and relatively barren. This is the SCHUCHERTELLA ELEGANS ZONE. *S. elegans, Paræchmina postica, Dizygopleura symmetriea,* and *Kloedenella cornuta* are common. There is no marked lithologic change at the base. 9 9

CLINTON GROUP

ROCHESTER SHALE

Thin-bedded gray shale with much interbedded gray, finely crystalline limestone in upper part, especially in the upper 10 feet. A prominent 1½-foot bed of limestone 51½ to 53 feet; a prominent 6-inch bed of limestone at 49 feet. These beds constitute the DREPANELLINA CLARKI ZONE. *Stropheodonta proutyi* and var., *Camarotœchia neglecta,* and *Drepanellina clarki* are common to abundant throughout. *Schuchertella subplana* and *Uncinulus stricklandi* occur in the lower part. For fuller description of fauna, see section southeast of Barree. A marked flattening of the dip occurs in the lower part of this shale. 58 58

KEEFER SANDSTONE

(For description of Keefer at this locality, see section described on p. 41.)

The Rabble Run red bed member is well exposed along the highway to Alexandria, just south of Barree, beginning about 150 feet south of the entrance of a lane leading west from the highway. The section here is as follows:

Section of part of McKenzie formation

Along and near highway to Alexandria, about 0.2 mile south of Barree, Pennsylvania. Measured with assistance of F. M. Swain and F. C. Whitmore, Jr

McKENZIE FORMATION

UPPER SHALE AND LIMESTONE MEMBER *Feet* *Bed Total*

Mostly concealed. Thin-bedded greenish shale and loose slabs of limestone containing *Camarotœchia andrewsi, Homeospira marylandica, Leiopteria (?)* sp., *Beyrichia mesleri, Kyammodes tricornis,* and *Kloedenella gibberosa* are seen in washways in a field east of a telephone cable line which crosses the highway about 0.3 mile south of Barree; or S40°E mag., 600 to 650 feet from the entrance of the lane leading west from the highway about 0.2 mile south of Barree. Some loose barren slabs of arenaceous limestone are seen along the cable line near the highway; loose slabs with *K. gibberosa* are also seen along the highway about 1,200 feet south of the cable line.

RABBLE RUN RED BED MEMBER

Thick-bedded dark red shale or siltstone, breaking across bedding and into irregular fragments. Some greenish splotching. Upper 10 feet poorly exposed where cable line crosses highway, but represented by red soil in bank. The upper part is exposed in the road gutter for several hundred feet south of the line, about along the strike. Approximately:	40	55
Thin-bedded shale weathering green, and some interbedded very argillaceous limestone. 10-inch bed of pinkish to red shale just below top.	12	15
Pinkish shale, breaking into irregular fragments.	3	3

LOWER SHALE AND LIMESTONE MEMBER

Mostly concealed; thin-bedded greenish shale exposed just below red beds and at several places to lane leading west from highway, about 150 feet north of base of red beds. Shale and limestones of the lower McKenzie can be seen along the lane, and Rochester shale is exposed along the lane about ¼ mile west of the highway.

The upper shale and limestone member of the McKenzie is partly exposed with underlying and overlying red beds, about 2 miles northeast of Barree. On the north side of Little Juniata River, about 1½ miles east of Barree, a dirt road leads north from the highway to Petersburg, and parallels the Keefer ridge of the east limb of Leading Ridge anticline. About 1 mile from the Barree-Petersburg highway, a second dirt road forks to the east, exposing the section.

Section 2 miles northeast of Barree, in east limb of Leading Ridge anticline.

Traverse begins at intake of culvert at the road forks, and then runs along the fork leading southeast. Measured with assistance of F. M. Swain and F. C. Whitmore, Jr. Bearings magnetic.

	Feet	
WILLS CREEK SHALE	*Bed*	*Total*
Concealed to east. Some green shale in gutter, and along bank of run south of road.		
BLOOMSBURG RED BEDS		
Concealed. Much red soil in bank. Traverse S77°E 15 feet.	5	52
Dark red shale or siltstone, breaking across bedding. Traverse S77°E 28 feet.	10	47
Concealed; some red soil at 30 feet traverse. Traverse S77°E 55 feet.	19	37
Arenaceous shale, weathering greenish, below; thin-bedded arenaceous very impure greenish limestone, weathering yellowish, at top. N59°E 29°SE. Traverse S66°E 10½ feet.	4	18
Thin- to medium-bedded dark red argillaceous sandstone and interbedded dark red arenaceous shale, breaking into irregular fragments. Lower 2½ feet slumped. N62°E, 33°SE. Traverse S66°E 26 feet.	11	14
Medium-bedded greenish and pinkish argillaceous sandstone; slumped.	3	3

McKENZIE FORMATION

UPPER SHALE AND LIMESTONE MEMBER

Largely concealed. Soil green. Some medium-bedded greenish argillaceous sandstone, slumped and loose, 258 to 282 feet traverse. Thin-bedded shale, weathering green, 160 to 182 and 90 to 131 feet of traverse; some of the shale is loose; some is in place, though slumped. With the shale is much fosiliferous limestone, mostly loose, containing *Camarotœchia andrewsi, Homeospira marylandica, Beyrichia mesleri, Kyammodes tricornis, Kloedenella gibberosa,* and other species of the KLOEDENELLA GIBBEROSA ZONE. At 100 feet traverse, some barren arenaceous limestone. Traverse S42°E 282 feet, drop 15 feet.	110	110

RABBLE RUN RED BED MEMBER

Dark red shale or siltstone, breaking into irregular fragments. Base of exposure at culvert intake on northwest side of road at forks. Partly concealed. N29°E, 22°SE. Traverse S59°E 112 feet, drop 13 feet.	28	28
Concealed west of road.		

The upper McKenzie can also be seen at the axis of an anticline about three-quarters of a mile north of Alexandria, in a badly washed hollow 500 to 1,000 feet west of the highway to Barree. Fossiliferous limestone can be obtained in place in the shale. Bloomsburg red beds are seen near the head and mouth of the hollow. Dips in the McKenzie are in part obscured by creep.

The fossil zones occurring in the McKenzie of the Barree area correspond to those established by the writer at Mount Union, Lewistown, and Lakemont, Pennsylvania (20, 21). These zones are also present in the McKenzie in the type area near Cumberland, Maryland, where the Rabble Run member tongues out. The Rabble Run red bed was named by C. K. Swartz from exposures in Washington County, Maryland (10). As shown by C. K. Swartz and the writer, the Rabble Run becomes incorporated in the basal part of the Bloomsburg in eastern and in north-central Pennsylvania, and is a tongue from the base of that formation as developed in the type area near Bloomsburg, Columbia County, Pennsylvania (16, 20).

Correlation of the McKenzie with New York horizons is made difficult because the characteristic ostracode assemblages of the McKenzie have not been found in that State. Instead, the Lockport dolomite, which occupies an analogous position above the Rochester shale and below Vernon or Bloomsburg red shale, is characterized by numerous coralline and molluscan species, of which few have been found in Pennsylvania and Maryland.

In view of these relationships, together with important changes in the ostracoda which occur in passing from the Rochester into the McKenzie, and certain affinities between the ostracoda of the McKenzie and those of the younger Wills Creek and Tonoloway formations, Ulrich and Bassler have suggested that the McKenzie is post-Lockport in age; and that the Lockport is absent in central Pennsylvania and farther south by virtue of an hiatus between the McKenzie and the *Drepanellina clarki* zone (24, 25). In the fine section at Lakemont, near Hollidaysburg, 8 miles southwest of the Tyrone quadrangle, they

placed the Rochester-McKenzie boundary at the base of a "reef-like bed," corresponding about to the top of the *Whitfieldella marylandica-Kloedenia ventralis* zone as described in the sections near Barree.

The writer has shown that the faunal succession across this horizon is more complex than was previously understood (20, 21). Thus both the *Schuchertella elegans* and *Whitfieldella marylandica-Kloedenia ventralis* were included in the *Drepanellina clarki* zone at Lakemont and elsewhere. No important change in the ostracoda occurs at the base of the "reef-like bed" at Lakemont; instead, *Kloedenia ventralis* and several other ostracoda pass across it from the *Whitfieldella marylandica-Kloedenia ventralis* zone into unquestioned McKenzie beds. The most complete ostracode change occurs at the top of the *Schuchertella elegans* zone. However, the base of the *S. elegans* zone is commonly more abrupt as seen in the field, and has provisionally and rather questionably been used by the writer for the formational boundary. The *S. elegans* zone might well be included in the Rochester, placing the Rochester-McKenzie boundary 8 feet higher in the Barree section.

None of the zonal boundaries seems to represent a faunal change adequate to account for absence of the Lockport by unconformity. Near Lock Haven, Clinton County, Pennsylvania, coralline beds containing *Favosites niagarensis* and *Cladopora multipora* appear in the lower part of the McKenzie. These relationships have led the writer to suggest that the McKenzie and Lockport may be divergent facies of about the same age (see Figure 3). Unfortunately, the McKenzie horizon is buried below younger sediments between the Lock Haven region and the area of outcrop of the Lockport in western New York. Consequently, the interfingering of the ostracode-rich beds with coralline beds, seen in a limited way near Lock Haven, cannot be further studied along the outcrop. Further data may eventually be made available by records from deep wells in the intervening area, or perhaps by discovery of some of the McKenzie ostracoda in areas in which Lockport faunas are better represented.[12]

BLOOMSBURG RED BEDS

The Bloomsburg red beds were named by I. C. White (29) from the town of Bloomsburg, Columbia County, Pennsylvania. As shown by C. K. Swartz and the writer, the formation becomes about 2,000 feet thick in parts of eastern Pennsylvania (16). Toward the west, it tongues out by interfingering with McKenzie, Wills Creek, and Tonoloway beds. The main western tongue occurs between the McKenzie and Wills Creek formations, and it is this tongue to which the name Bloomsburg is applied in this discussion of the Tyrone area. Since this tongue is only about 50 feet thick in the Barree region, and because of other considerations discussed in the section dealing with the

[12] It is obviously impossible to determine certainly the relations of the Lockport and McKenzie. From the facts of paleontology above stated by Mr. Swartz, their correlation is reasonable. On the other hand the occurrence of the corals in the base of the McKenzie near Lock Haven may indicate the feather edge of the southward thinning Lockport which is there overlapped by the younger McKenzie.—Butts. The coralline beds near Lock Haven occur within the *Beyrichia moodeyi zone*. They interfinger with, and are not simply overlapped by, unquestioned McKenzie beds.—F. M. S.

McKenzie formation, the Bloomsburg red beds are united with the underlying Rabble Run and upper members of the McKenzie, and the overlying Wills Creek shale, in the Areal Geology map.

As seen in the section 2 miles northeast of Barree (pp. 45-46), the Bloomsburg beds consist of softer red shale, above, and of red shale and sandstone, below, separated by 4 feet of green shale and very impure limestone. The latter beds are suggestive of the Cedar Cliff limestone member of the Bloomsburg near Cumberland (10). However, correlation with that member is scarcely warranted at the present time.

The details of the red bed horizons have not been worked out near Tyrone because of limited exposures. The writer has shown that the Rabble Run red bed is present about 100 feet below the top of the McKenzie at Lakemont, 17 miles southwest of Tyrone (21). Near and to the northeast of Howard, Centre County, Pennsylvania, 25 miles northeast of the Tyrone quadrangle, the upper McKenzie has changed to red shale, and the Rabble Run beds are merged with the Bloomsburg formation (see Figure 3). Red shale shows just below an altitude of 1,200 feet on the northwest slope of Bald Eagle Mountain, on the road to Scalp Level, about three miles southwest of Tyrone; also at 1,000 feet altitude on the east bluff of Bald Eagle Creek, near the water tank opposite the paper mill at the north end of Tyrone.

C. K. Swartz and the writer (16), as well as other workers, regard the red High Falls shale of southeastern New York and red Vernon shale of western New York as extensions from the Bloomsburg of central Pennsylvania.

WILLS CREEK SHALE

In the description of the Pawpaw-Hancock folio (8), the Wills Creek shale was named by Stose from exposures along Wills Creek, at Cumberland, Maryland. The Wills Creek section, and the better section at Pinto, eight miles south of Cumberland, were subsequently described by C. K. Swartz (10).

The thickness of the Wills Creek in the Tyrone quadrangle has not been carefully determined, but is probably about 500 feet. The formation crops out in a narrow belt low down on the northwest slope of Bald Eagle Mountain, and in a rather broad belt in the low land east of Tussey and Round Top Mountains and Leading Ridge. It is largely composed of greenish and a little pinkish shale, which weathers readily so that exposures of bedrock are in general not common or extensive; but its presence beneath the surface is characteristically denoted by soft clayey soil, commonly full of chips of greenish to yellowish shale, and with few limestone fragments. Near the base is a peculiar thin bed of laminated limestone that is conspicuous in some fields where the soil is thin.

Parts of the formation are exposed for some distance in two cuts along U. S. Highway 22, about 1.3 to 1.5 and 2 miles, respectively, southeast of Alexandria. The first exposes green and some pinkish shale, much contorted. The second shows green shale, apparently higher in the formation.

The Wills Creek is much better exposed along the north side of the Juniata River opposite Mount Union, about 10 miles southeast of the Tyrone quadrangle (20). It is there about 455 feet thick. Many of the beds weather to the peculiar pea-green color characteristic of much of the formation as seen in bluffs. A considerable portion of the shale or mudrock is rather poorly bedded and breaks down into irregular or hackly fragments. There are occasional thin beds of pinkish shale, which become more abundant and deeper red in the Wills Creek as seen along the Pennsylvania Railroad about 1 mile east of the station at Lewistown, Mifflin County, 23 miles east of the Tyrone quadrangle. These changes illustrate the interfingering relation of the dominantly green Wills Creek, toward the west, with part of the Bloomsburg red beds, which thicken eastward.

Fossils are rare in the Wills Creek of the Tyrone quadrangle, and the writer found no determinable species in the Wills Creek at Mount Union and Lewistown. There are a few ostracoda in some of the lower beds of the formation near Barree; but these have not been studied. Stratigraphic relations with Bloomsburg and Tonoloway formations suffice to show essential equivalence with the type Wills Creek of western Maryland. The interfingering relationships of the Wills Creek of the Tyrone-Mount Union area with the Bloomsburg red beds of more easterly sections have already been discussed. In stratigraphic position and lithology, the Wills Creek is suggestive of the Camillus shale of western New York. However, recent work by the writer near Williamsport, Lycoming County, shows that the overlying Tonoloway limestone undergoes a marked reduction in thickness in that area. There is some reason to believe that this occurs by a change of lower parts of the Tonoloway into shales of Wills Creek type; while an uncertain portion of the Wills Creek of the Tyrone area is presumably transformed into Bloomsburg red beds (see Figure X). If this should be the true relationship, it is very likely that the Camillus shale of New York is to a considerable extent equivalent in age to the Tonoloway limestone, rather than to the Wills Creek shale of the Tyrone area.

TONOLOWAY LIMESTONE

The Tonoloway limestone was named by Stose (8) from Tonoloway Ridge in Washington County, Maryland, and Morgan County, West Virginia. In the Tyrone quadrangle, it crops out in a narrow strip at the northwest base of Bald Eagle Mountain and in a rather broad area diagonally crossing the southeast quarter of the quadrangle. Small exposures occur in the bluff of Bald Eagle Creek at the north end of Tyrone. There are extensive exposures in cuts along U. S. Highway 22, about 2½ to 4 miles by road southeast of Alexandria. There are good exposures on the east side of the Juniata River near Petersburg, and on the south side of the river, to the southwest of that town.

Because of the low dips and minor folding, it is difficult to obtain satisfactory measurements of the thickness of the Tonoloway in the Petersburg area. The dips are higher, and the structure of the Tonoloway is apparently simple in the following section which was measured near Grafton, about 5 miles south of the Tyrone quadrangle and 7 miles southwest of Huntingdon, Pennsylvania.

Section of the Tonoloway limestone

Along a road leading northwest from Grafton, Pennsylvania, through a gap in Warrior Ridge. All bearings magnetic.

	Feet Bed	Total
KEYSER LIMESTONE		
Thick-bedded, somewhat crinoidal and crystalline limestone, weathering dark gray, about 12 feet below; thinner bedded, more argillaceous limestone, and some thick-bedded limestone, above. About 40 to 50 feet of the lower Keyser are exposed in the hanging wall of a quarry north of the road, on the northwest slope of Warrior Ridge. The Keyser beds were not measured at this place.		
TONOLOWAY LIMESTONE		
Dense to finely crystalline dark gray limestone, exposed in quarry. The limestone is more or less thinly laminated for the most part; but is irregularly bedded to somewhat lumpy 6 to 9 feet above the base. These beds weather to a light bright gray, which is conspicuous against the darker beds of the overlying Keyser. N43°E, 33°SE.	51	771
Mostly concealed, but with occasional exposures of laminated dense limestone. Traverse begins at northeast end of quarry at an horizon 10 feet above base of beds exposed in quarry; then runs N66°W 175 feet along slope, drop 29½° to side of road; then along road as follows: traverse N6°W 209 feet, total 384 feet.	220	720
Concealed, with much platy and some thin-bedded limestone loose in road cut. Traverse N6°W 80 feet, N16°W 240 feet, total 704 feet.	140	500
Concealed. Traverse N23°W 135 feet, N51°W 265 feet, N22°E 27 feet, total 1,131 feet. Culvert for small run at 957 feet traverse.	220	360
Thin- to medium-bedded, some laminated, rather impure limestone, and a little interbedded calcareous shale; partly concealed. N39°E, 37°SE. Traverse N22°E 131 feet, total 1,262 feet.	18	140
Concealed. Traverse N22°W 179 feet, total 1,441 feet.	24	122
Thin- to medium-bedded impure limestone and some interbedded calcareous shale, which weathers green to yellow. N38°E, 32°SE; N37°E, 35°SE. Traverse N22°E 43 feet, N5°E 50 feet, N19° W 26 feet, total 1,560 feet.	33	98
Concealed. Traverse N19°W 88 feet, total 1,648 feet.	40	65
More or less laminated dense dark blue relatively pure limestone, weathering light blue gray and platy. Traverse N19°W 56 feet, total 1,704 feet. N35°E, 34°SE (average of 3 observations).	25	25
WILLS CREEK SHALE		
Concealed along road leading northwest. Middle of Highway No. 26, McConnelstown to Marklesburg, at 2,080 feet traverse. Interval may include some Tonoloway limestone at top. Much green calcareous shale of typical Wills Creek is exposed, however, along the highway south of intersection, beginning about opposite 2,070 feet traverse. These beds show some minor folding; but a representative strike and dip is about N22°E, 27°SE. Traverse was run by tape to 1,704 feet, then by pacing to 2,724 feet, then was estimated by car speedometer to 3,600 feet. Traverse N26°W, 340 feet, N38°W 120 feet, total about 2,165 feet.		
Green calcareous shale, partly concealed, seen in bed of road northwest of intersection with highway. Strike N43°E; dip uncertain, possibly 63°SE at one place, suggesting some minor folding. Traverse N59°W 140 feet, total about 2,305 feet.		
Concealed, with much green shale loose in bank in upper part of interval. Traverse N81°W 420 feet, N68°W about 600 feet, N56°W about 300, total about 3,600 feet.		

BLOOMSBURG RED BEDS (?)

Thick-bedded red argillaceous sandstone at top, underlain by some red and some green shale, partly concealed. Upper part presumably Bloomsburg, but not studied. N28°E, 23°SE.

The thickness of 770 feet obtained for the Tonoloway limestone in the above-described section, is probably about correct. Although there are extensive concealed intervals, the strikes and dips of the exposed beds are comparatively constant. This thickness is close to that obtained by the writer at Mount Union, 10 miles southeast of the Tyrone quadrangle, where the Tonoloway measures 720 feet (20). Because of the uncertainty as to dips, and the evident minor folding, the above section does not provide a satisfactory estimate of the thickness of the Wills Creek. Using the average of the strikes and dip of the underlying Bloomsburg and overlying basal part of the Tonoloway, a thickness of about 800 to 850 feet is obtained. This is out of harmony with other measurements through the general region, and is most probably too great. It is also possible that the red beds at the base of the section as described are Rabble Run and not Bloomsburg. The section needs more study than was devoted to it during a short visit.

In the section at Mount Union, the Tonoloway exhibits the following lithologic divisions and faunal horizons, listed in stratigraphic order (20):

Tonoloway limestone at Mount Union

	Feet
Hard, fairly pure, in part thinly laminated limestone, weathering bluish gray.	120
Impure, more or less dolomitic limestone, the upper 200 feet weathering buff and earthy, the lower part weathering grayish. Basal 85 feet mostly concealed, may belong with next underlying beds.	385
Thin- to medium-bedded, hard, in part laminated, comparatively pure limestone. Contains in upper part a zone of *Hindella congregata* with *Zygobeyrichia regina* and other ostracoda.	145
Argillaceous limestone and drab gray calcareous shale; at top are 40 feet of calcareous shale, weathering green and somewhat hackly, like the characteristic shale beds of the Wills Creek.	160
Hard limestone, weathering bluish gray. *Welleria obliqua* occurs in these beds farther north at Strodes Mill, near Lewistown.	9

The extent to which these divisions and faunas are represented in the Tonoloway of the Petersburg-Grafton area is not known. The *Hindella congregata fauna* at the middle of the Tonoloway at Mount Union is also characteristic of the middle Tonoloway in Maryland (10).

In the section of the uppermost Tonoloway and Keyser ¼ mile south of Warrior Ridge settlement, as hereinafter described, the Cobleskill ostracode *Leperditia scalaris* occurs in considerable abundance 40 to 50 feet below the top of the Tonoloway. During the past two years, the writer has obtained this species in abundance at Lewistown in Mifflin County, Beaver Springs in Snyder, Mexico in Juniata, Clarks Mill and Falling Springs in Perry, and Dalmatia and Selinsgrove Junction in Northumberland, all in central Pennsylvania (22).

Except at Mexico, *L. scalaris* was found at these localities only in beds which lie above the typical laminated limestones of the upper Tonoloway. Furthermore, the writer recently obtained the species 22 feet above the base of the Keyser at the type section at Keyser, West Virginia. Accordingly, the beds containing the *L. scalaris* fauna at the above localities have been regarded as basal Keyser. At Mexico, collections made before the *L. scalaris* zone was recognized contain *L. scalaris* both from beds which were regarded as uppermost Tonoloway, and also from the lower part of the Keyser limestone. The writer has recently obtained *L. scalaris* from the Bossardsville limestone in a section near Schuylkill Haven in Schuylkill County, studied by C. K. Swartz.

The significance of these occurrences is open to several interpretations. It may be that the Tonoloway-Keyser contact as drawn by the writer varies in age from place to place; and that the *L. scalaris* beds at Clarks Mill, included in the Keyser by both Reeside and the writer, are equivalent to *L. scalaris* beds at Lewistown which were mostly referred to the Tonoloway by Reeside, but to the Keyser by the writer (22), and to the *L. scalaris* beds at Warrior Ridge which clearly belong in the Tonoloway on the basis of lithology. It may be that the range of the species is somewhat different in time at the different places. In any event, the species provides additional evidence of the relatively intimate relations of the Tonoloway and Keyser through most of central Pennsylvania.

The relations of the Tonoloway to the Keyser, above it, and the Wills Creek, below it, and the occurrence at Mount Union of *Hindella congregata* in the middle Tonoloway and *Welleria obliqua* in its lower part, show that the Tonoloway of the Mount Union and presumably the Petersburg areas is closely equivalent to the Tonoloway of Maryland; except, perhaps, for the uppermost beds containing *Leperditia scalaris*. There is evidence that the Tonoloway, at least in part, intertongues to the east with the Bloomsburg red beds (10, 16). In the Williamsport area in north-central Pennsylvania, the Tonoloway thins, very likely by change of much of its lower part to shales of Wills Creek type (see Figure X). The latter change favors correlation of the Tonoloway of the Tyrone area with part of the Camillus shale, together with the Bertie limestone of western New York. The *Leperditia scalaris* beds at the top of the Tonoloway at Warrior Ridge may well be equivalent to beds which the writer has included in the basal Keyser at other localities in central Pennsylvania, to the Bossardsville of eastern Pennsylvania, and perhaps to part of the Cobleskill of western New York.

KEYSER LIMESTONE

The name Keyser limestone was first used by Ulrich in 1911 (26), and its fauna was discussed by him in 1912 (8). The name was taken from the fine section exposed in quarries at Keyser, West Virginia, which had been described by Schuchert in 1903 (6). However, the characteristics, limits, and faunal zones of the Keyser at Keyser were fully described first by C. K. Swartz and others in 1913 (9, 13, 14).

The Keyser has been included in the Helderberg group and Devonian system by Ulrich (26), C. K. Swartz (9), Reeside (5), and the writer in various papers (18, 19). The writer has recently suggested that the Keyser be separated from the Helderberg group and placed in the Silurian system (22), a procedure which is also favored by C. K. Swartz and others. The Keyser limestone is united with the Helderberg group in the Areal Geology map.

The Keyser limestone and Helderberg group occupy two narrow belts on Cemetery Hill, Tyrone, which converge northeastward and join. They also crop out in an irregular fashion across the southeastern corner of the quadrangle.

The Keyser is about 100 feet thick in the Tyrone quadrangle, as compared to 280 feet at Keyser, West Virginia. Its characters and faunas are brought out by the following sections. The first represents the Keyser of the northwestern part of the quadrangle and is summarized from the description by J. B. Reeside, Jr. (5).

Section of the Keyser limestone.

Beginning just behind house on southwest corner of Lincoln and Fifteenth Streets, Tyrone; then extending along small stream known as Sink Creek. Summarized from description by J. B. Reeside, Jr.

	Feet Bed	Feet Total
COEYMANS LIMESTONE		
Impure shaly limestone, above; thick-bedded, gray, coarsely crystalline limestone, below. Base sharply defined. Near middle: *Gypidula coeymanensis* and other fossils.	8½	8½
KEYSER LIMESTONE		
Dense, largely laminated limestone, weathering gray to brownish, and some calcareous shale. *Leperditia* sp. at base.	20	90
Thick-bedded limestone, formed by a stromatoporoid reef.	2½	70
Shaly limestone, weathering yellowish.	2	67½
Thick-bedded limestone, composed of corals, bryozoa, and stromatoporoides, the latter more abundant in the upper part. Dense shaly limestone 16 to 17½ feet above base, and 6 inches of shale at base.	27	65½
Coarsely crystalline gray limestone. In upper half, CALYMENE CAMERATA SUBZONE: *Favosites* sp., *Aulopora* sp. *Levenea (?) concinna, Rhipidomella emarginata, Calymene camerata.*	7½	38½
Thick-bedded coarsely crystalline limestone. CORAL SUBZONE: *Cladopora rectilineata, Halysites catenulatus* (a), *Aulopora* sp., *Favosites* sp., stromatoporoides.	7½	31
Thick-bedded light gray coarsely crystalline limestone, below, becoming thinner bedded above.	8½	23½
Thin-bedded gray limestone and interbedded shale. STENOCHISMA DECKERENSIS SUBZONE: *Cladopora rectilineata, Leptæna rhomboidalis, Stenochisma deckerensis, Atrypa reticularis, Spirifer octocostatus, Nucleospira* sp., *Orthoceras* sp.	1½	15
Thick-bedded coarsely crystalline limestone, upper 4 feet standing out as a ridge.	8½	13½
Finely crystalline drab limestone, thick-bedded above, thin-bedded below. At 1 foot: *Levenea (?) concinna, Leptostrophia bipartita, Schuchertella deckerensis, Camarotœchia litchfieldensis, Atrypa reticularis, Spirifer eriensis?*	5	5

TONOLOWAY LIMESTONE

	Feet Bed	Total
Thick-bedded dense limestone, weathering buff; some interbedded chert in lower part.	3½	92½
Dense limestone, largely laminated and weathering into thin plates, and some interbedded calcareous shale. Some thin lenses of chert 27 to 33½ feet below top; some siliceous oolite 73½ to 76 and 82 to 92 feet below top of Tonoloway.		106
Concealed.		

The next section represents the Keyser of the southeastern as compared to the northwestern part of the Tyrone quadrangle, and exhibits important faunal differences. The collections are representative but not complete.

Section of Keyser limestone

In bluff along Pennsylvania Railroad, on east side of Juniata River, about ¼ mile south of Warrior Ridge settlement, and 2½ miles south of Petersburg, Pennsylvania.

	Feet Bed	Total
COEYMANS LIMESTONE		
Thick-bedded gray crystalline limestone, seen as loose slabs above top of bluff. Ridgeley sandstone is seen on hill to east; intervening beds concealed.		
KEYSER LIMESTONE		
Concealed, with much thinly laminated limestone of upper Keyser type on surface; about	10	121
Thinly laminated dense limestone. Lower 4 feet less clearly laminated than most of the remainder. Upper 10 feet partly concealed. At 79 feet: cf. *Schuchertella deformis,* but small, (a) *Uncinulus* sp. (r), *Rensselæria mutabilis* and vars. (c), *Spirifer vanuxemi* (a). At 78 feet: *Rensselæria mutabilis* and vars. (a), *Tentaculites gyracanthus* (aa), *Kloedenia centralis (?)* (c). These faunas represent the RENSSELÆRIA MUTABILIS-SPIRIFER VANUXEMI SUBZONE.	40	111
Thick-bedded rather finely crystalline fairly pure gray limestone, weathering dark gray. Stromatoporoid and *Favosites* reef in upper 2 feet. At 57 feet: MERISTA TYPA SUBZONE: Corals (c), *Atrypa reticularis* (c), *Merista typa* (a).	17	71
Medium-bedded, somewhat impure, finely crystalline gray limestone, more argillaceous below; upper part with 2-inch layers which weather light gray with greenish partings.	9	54
Thick-bedded gray crinoidal limestone, somewhat lumpy and weathering a rather dark gray. The lower part is more coarsely crystalline than the upper part. These beds contain a CLADOPORA RECTILINEATA SUBZONE, merged with the upper part of the GYPIDULA PROGNOSTICA SUBZONE. The latter continues into underlying beds, is exceptionally thick at this locality, and is also abnormal because it extends virtually to the base of the Keyser. *Cladopora rectilineata* (aa), with bryozoa and numerous pelmatozoan fragments, at 32 feet; *Gypidula prognostica* (a) at 44 feet.	23	45
Thin-bedded argillaceous lumpy limestone below and at top; thick-bedded, less argillaceous, somewhat lumpy limestone 5 to 11 feet above base. These and next underlying beds contain species characteristic of both the GYPIDULA PROGNOSTICA and STENOCHISMA DECKERENSIS, SPIRIFER MODESTUS SUBZONES. At 17 feet: cup		

corals (c), *Gypidula prognostica* (c), *Stenochisma deckerensis* (c), *Atrypa reticularis* (c), *Spirifer octocostatus* (r). At 10 to 12 feet: cup corals (a), *Strophonella* sp. (r), *Atrypa reticularis* (c), *Spirifer modestus* (c).	15	22
Thick-bedded, somewhat lumpy, fairly pure limestone, with numerous pelmatozoan fragments, especially in the lower part. Weathers dark gray with brownish stains, in marked contrast with underlying Tonoloway. Base is sharply defined, at times a little irregular, and at a few places contains fragments of light-colored limestone apparently derived from next underlying beds. 4 to 5 feet above base: Cup corals (c), Bryozoa (c), *Gypidula prognostica* (a), *Camarotœchia litchfieldensis* (r), *Stenochisma deckerensis* (c), *Atrypa reticularis* (c), *Spirifer modestus* (r).	7	7

TONOLOWAY LIMESTONE

Medium- to thick-bedded, dark, dense limestone, weathering light, bright gray, in marked contrast with overlying beds. Thinly laminated in part, the laminæ sometimes rather irregular. Some lenses of dark chert 4½ feet above base this unit. Measured near north end of exposure.	27	55
Thinly laminated dense dark limestone weathering light bright gray.	5	28
Thin-bedded, dense, dark limestone, the layers commonly ½ to 1 inch thick; lower part irregularly bedded to almost lumpy. Weathers light bright gray. 4 to 12 feet above base of exposure: *Stenochisma lamellata* (r), *Leperditia scalaris* (a).	20	23
Medium-bedded dense gray limestone, weathering light bright gray. Seen at north end of exposure.	3	3
Concealed.		

Relations of the Keyser of the above sections with the formation as seen elsewhere in the middle Appalachian area are indicated by comparisons with the following table of faunal zones. Most of these zones are of regional significance in the Keyser through central Pennsylvania (5, 22), western Maryland (9), and, except for the *Leperditia* zones, in the areas of Keyser outcrop in the Virginias.

Favosites helderbergiæ var. *præcedens* zone

12. *Leperditia altoides?* subzone.
11. *Meristella prænuntia, Tentaculites gyracanthus* subzone, ranging downward through the *Rensselæria mutabilis* suzbone, and in central Pennsylvania best developed toward Perry County.
10. Upper Stromatoporoid beds, including several distinct reefs of varying position and extent.
9. *Leperditia gigantea* subzone.
8. *Rensselæria mutabilis* subzone, with associated subzones of *Pholidops ovata* and *Spirifer vanuxemi.*
7. Upper coral reef, with *Cladopora rectilincata.*

Chonetes jerseyensis zone

6. Bryozoan subzone, locally with especial abundance of *Calymene camerata.*
5. *Merista typa* subzone, frequently with *Camarotœchia gigantea;* sometimes extending above subzone no. 6.
4. *Gypidula prognostica* subzone.
3. Lower coral and stromatoporoid beds, with *Cladopora rectilineata* and *Halysites catenulatus.* These interfinger with subzone 2, and, in central Pennsylvania, are best developed toward the west and north.

2. *Stenochisma deckerensis, Spirifer modestus* subzone, with *Cyphotrypa corrugata* and, especially in lower part, *Rhynchospira globosa.*
1. *Leperditia scalaris* subzone. In central Pennsylvania, this subzone or zone lies below the known range of *Chonetes jerseyensis,* and occurs in both basal Keyser and uppermost Tonoloway beds.

As was noted by Reeside, the rarity if not complete absence of *Tentaculites gyracanthus, Rensselæria mutabilis, Spirifer vanuxemi,* and *Meristella prænuntia* is a notable feature of the upper Keyser in both of the sections which he studied at Tyrone. The persistent middle Keyser species *Merista typa* and *Gypidula prognostica* also were not found at Tyrone by Reeside, but are abundant at Warrior Ridge. Corals are nearly as abundant in the lower Keyser at Warrior Ridge as they are at Tyrone.

At Warrior Ridge, *Gypidula prognostica* appears within 4 feet of the base of the Keyser. At Lewistown, Mifflin County, it occurs 41 to 52 feet above the base of the Keyser as described by Reeside, about 80 to 90 feet above the base if the *Leperditia scalaris* beds are included in the Keyser and the Keyser-Tonoloway contact is placed at the top of the thinly laminated limestones of Tonoloway type, as was recently done by the writer (22). At Keyser, West Virginia, *G. prognostica* occurs 133 to 135 feet above the base of the Keyser, *M. typus* 169 feet above the base, *R. mutabilis* at 195 feet, and *L. scalaris* at 22 feet. At Warrior Ridge, *G, prognostica* apparently ranges into somewhat lower parts of the Keyser than at Keyser; but part of the lower Keyser at Keyser and Lewistown appears to be absent by unconformity, and the basal part may be represented by the *L. scalaris* beds which belong, on the basis of lithology, in the upper Tonoloway at this locality. The sharp definition of the contact between the Keyser and Tonoloway at Warrior Ridge, the occurrence in the basal Keyser of a few fragments apparently derived from the underlying beds, provides strong physical evidence of an hiatus. Furthermore, the Keyser is only about 120 feet thick at Warrior Ridge, as compared to 280 feet at Keyser.

The upper laminated beds, seen at both Warrior Ridge and Tyrone, are characteristic of the upper Keyser through much of western Maryland and central Pennsylvania. The lower beds at Warrior Ridge are in part somewhat lumpy, but this feature is less marked than usual and is scarcely if at all developed at Tyrone. Along with this reduction in lumpy structure, there is a concomitantly greater proportion of rather coarsely crystalline limestone.

The contact between the Keyser and overlying Coeymans limestone is not seen at Warrior Ridge, but is sharply defined in the section at Tyrone, as is true generally in central Pennsylvania and elsewhere. This contact is believed to represent a widespread, though not long continued, break in sedimentation, and is one of the reasons for separating the Keyser limestone from the Helderberg group and for placing it in the Silurian system.

The fauna of the lower Keyser is closely related to that of the Decker limestone of New Jersey (28), and agrees in some important respects with that of the Cobleskill limestone of central New York (3). The *Spirifer vanuxemi* and *Tentaculites gyracanthus* of the upper Key-

ser are characteristic species of the Manlius of central New York and also of the beds so named in New Jersey. However, other important species of the upper Keyser, such as *Rensselæria mutablis* and *Meristella prænuntia*, have not as yet been discovered in the Manlius, so that relations of that formation to the upper Keyser need further investigation.

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DEVONIAN SYSTEM*

By Bradford Willard

The Devonian system has a wide distribution in Pennsylvania, and occupies two areas in the Tyrone quadrangle. In the northwestern corner, a triangle of Devonian rocks is bounded on the southeast by the east slope of Bald Eagle Creek valley, and on the north and west by the respective edges of the quadrangle. The second area also is triangular, and is of a size somewhat less than the first. It lies in the southeastern corner of the quadrangle north and northwest from Huntingdon. The Devonian system in Pennsylvania is one of the thickest, and measures nearly 9,000 feet in the Tyrone area. It is composed chiefly of clastic sediments and is devoid of any igneous or metamorphic elements. The generalized sequence along the Allegheny Front is as follows:

Generalized section of the Devonian system.

Catskill continental facies, red beds	2500
Chemung group, shale and sandstone	2500
Portage group	
Brallier greenish shale	1800
Harrell gray shale	100-200
Burket black shale	50-75
Tully limestone (not exposed)	10 (?)
Hamilton group	
Mahantango shale	1000
Marcellus black shale	150-200
Onondaga group	50 (?)
Oriskany group	
Ridgeley sandstone	200
Shriver chert	150
Helderberg group	
Mandata shale	20
New Scotland limestone	14
Coeymans limestone	8

HELDERBERG GROUP

The name Helderberg has long been in use in the geologic literature of eastern North America, and was first applied to limestones in the Helderberg Mountains southwest of Albany, New York. It has since, as a stratigraphic term, undergone much revision and change. It is now recognized as a group term in Pennsylvania and adjoining states. As such it consists of three units in the Tyrone quadrangle:

Mandata shale
New Scotland limestone
Coeymans limestone

* In preparing this discussion Dr. Butts's original manuscript has been entirely revised. His material has been used jointly with data collected by Willard.

Much of our present knowledge of the Helderberg group in Pennsylvania is due to the works of J. B. Reeside and F. M. Swartz. Until recently the Keyser limestone was grouped with the Helderberg, but this is no longer the case. The Keyser is now conceded to be uppermost Silurian and is so treated in the survey's forthcoming bulletin on the Devonian of Pennsylvania. However, in the geologic map of the Tyrone quadrangle the Keyser has not been differentiated from the Helderberg group. F. M. Swartz recognizes the Mandata black shale at the top of the group in central Pennsylvania. It is closely related to the New Scotland limestone.

The Helderberg group and Keyser limestone occupy two areas in the Tyrone quadrangle. In the northwestern part a narrow band follows southwestward along the east side of Bald Eagle Valley to Vail where it is structurally divided into two parallel bands and as such is probably continuous through Tyrone borough and on toward the west side of the map. The second area of Helderberg in the Tyrone quadrangle is in the southeastern quadrant. There, along the west slope of northeast-trending Warrior Ridge, a wide and irregular band winds northeastward from south-central Porter township to pass out of the quadrangle east of Swamp School. From this area extensions are prolonged south along the Juniata River from Petersburg nearly to the south edge of the quadrangle at Huntingdon.

Exposures of the Helderberg limestones are common. In Tyrone they are encountered at the north end of Pennsylvania Avenue and in small hills at the north end of the borough. Reeside described in detail a section at Lincoln and Fifteenth Streets, Tyrone.

There is a sharp lithologic change from the laminated upper beds of the Keyser to the overlying, coarsely crystalline Coeymans limestone. The Coeymans-New Scotland contact is not sharp, but is drawn below the first *Eospirifer macropleurus*-bearing bed. Reeside's detailed sequence[13] is abstracted by Butts thus:

	Feet
New Scotland limestone member: limestone, thick to medium thick-bedded with occasional shaly layers, coarse and fine-grained, gray, somewhat cherty. *Eatonia medialis, "Spirifer" cyclopterus, "S." macropleurus, "S." perlamellosus, Dalmanites micrurus, Phacops logani*	14
Coeymans limestone member: limestone, shaly and yellowish at top, thick-bedded to massive, coarse-grained, gray below, cherty in middle. *Gypidula coeymanensis,* the guide fossil of the Coeymans member, and a few other fossils	8
Keyser limestone member:[14] all limestone, thick-bedded, thin-bedded, laminated or shaly or nodular, argillaceous, fine-grained or coarsely crystalline layers, generally gray, some weathering buffish gray or yellowish, fossiliferous. *Stromatopora, Cladopora rectilineata, Chonetes jerseyensis, Nucleospria elegans, Orthostrophia strophomenoides, Rhynchospira globosa, "Spirifer" octocostatus, Stropheodonta bypartita, Strophonella leavenworthana* var. Also many bryozoans and ostracods	88

[13] Reeside, J. B., U. S. Geol. Survey Prof. Paper 108, pp. 207-9, 1917.

[14] See detailed section by Swartz, page 52.

According to the above section the Helderberg and Keyser are 130 feet thick at Tyrone, and but little greater thickness is indicated elsewhere in the area. The formations thicken southward to about 300 feet at Hollidaysburg and to 350 feet in the Cumberland, Md., region, the increase being chiefly in the Keyser member, which, at a maximum, is nearly 300 feet thick at its type locality at Keyser, W. Va.

The Helderberg group also shows along the valley of the Juniata River in bluffs in the southeast part of the quadrangle, and a good sequence is reported by Butts about ½ mile west of Huntingdon borough line. It may be seen also in railroad cuts southeast of Warrior Ridge station. Both the Coeymans and Keyser are recognized in this locality.[15] Swartz has recently recognized the Mandata dark shale above the New Scotland limestone at many places in central Pennsylvania. It is about 20 feet thick in the Tyrone quadrangle.

ORISKANY GROUP

The Helderberg group is succeeded by the Oriskany group. The name Oriskany is of long standing for a relatively thin, but persistently widespread formation or group typically developed in central New York, but continuing south through the Appalachians. Owing to the very recent work by Pennsylvania investigators, especially A. B. Cleaves of the Pennsylvania Topographic and Geologic Survey, the term Oriskany is today used as a group in this State and as such is subdivided into:

Ridgeley formation
Shriver formation

These names were first used in Maryland and West Virginia, but are quite applicable in the Tyrone quadrangle. In general there is a fairly clear separation between the Oriskany and Helderberg groups, but locally this appears to be obscure, both faunally and lithologically. The absence of the Becraft limestone in central Pennsylvania has been cited as ground for assuming a brief hiatus here between the two groups. The sharp Helderberg-Oriskany (Shriver) contact is exposed along the creek where it loops about the small hill at the north end of Tyrone (Plate 13, B.)

The Oriskany group has a distribution in the Tyrone quadrangle essentially similar to, though wider than, that of the Helderberg. A narrow band underlies part of Bald Eagle Creek Valley, but the rock rarely is exposed save near Tyrone. It is widely spread in the southeastern corner where it forms Warrior Ridge and the adjacent, relatively high terrane northwest of Huntingdon. The total thickness of the Oriskany group in the Tyrone quadrangle is put at 320 feet.

Shriver formation. The Shriver formation, the lower unit of the Oriskany group, is often referred to as the Shriver chert. It takes its name from Shriver Ridge, the type locality, at Cumberland, Maryland. In the Tyrone quadrangle the distribution of the Shriver is similar to that of the Ridgeley, though less extensive, and exposures are poorer. A narrow band follows the bank of Bald Eagle Creek.

[15] See section by Swartz, page 53.

It is also found along the northeast flank of Warrior Ridge and in the gorge of the Juniata River through that elevation. The Shriver shows to advantage on the knob at the north end of Pennsylvania Avenue, in Tyrone (see Plate 13, B), and it crops out on Cemetery Hill. Its presence may be detected in the absence of outcrop by the abundance of small, yellow chips or blocks which strew the surface and among which out-weathered fossils sometimes occur excellently preserved.

Lithologically, the freshly exposed Shriver usually is cherty. The chert is dark and impure and sometimes mingled with dark shale interbeds. The chert commonly weathers yellow. At Tyrone 120 feet of Shriver is recorded, and a similar thickness is indicated in the southeastern part of the quadrangle.[16]

Fossils are often abundant in the Shriver formation, and include, according to Butts and Swartz the following:

Chonetes hudsonica
Pholidops multilamellosa
Metaplasia plicata
Stropheodonta arctimuscula (?)
Bollia sagittaformis
B. zygocornis
Thilsura confluens
T. tricornis
Thlipsurella secoclefta

Swartz supplied the list of ostracoda in the above and remarks that they are persistent in the Shriver near Hollidaysburg, Lewistown, and Curtin, in central Pennsylvania. Of the above, the *Pholidops* and *Metaplasia* are particularly diagnostic of the Shriver formation in Maryland and central Pennsylvania, for they are unrecorded from older or younger beds. The remainder of the fauna is more typical of the Oriskany group as a whole. The fossils are often encountered in the Shriver in small pockets in the rock, and may be collected from weathered outcrops.

Ridgeley formation. The Ridgeley formation consists of sandstone with a varying amount of limy material and chert. Occasional conglomerates have been reported. In general the sand is rather coarse-textured. Because of its calcitic cement, the rock weathers readily and may be totally without topographic expression. Locally, its purity recommends its use as a source of glass sand. The type locality of the Ridgeley is at Ridgeley, W. Va. In the Tyrone quadrangle, it is that part of the Oriskany group most widely spread. North of Tyrone it may be observed in the small knob called Cemetery Hill (or Ridge) and also beyond on Bald Eagle Creek and in cuts on the highway north from Tyrone. The Ridgeley beds are further exposed in the valley of Bald Eagle Creek on the railroad 1½ miles southwest of Dix. All along this valley the rock is steeply dipping, in fact almost vertical, which appears to have an important influence in hastening the rate

[16] In my judgment the Shriver contains but little chert, although a few siliceous knots occur. In the Bald Hill section where freshly cut in 1918, it is predominantly a thin-bedded siliceous limestone which weathers to sandstone by leaching of the lime. On the whole as weathered, it is a fine-grained sandstone as shown in the exposure at the base of the knoll north of Tyrone (Plate 11, B).—Butts. I agree that the Shriver contains little, if any, typical chert in this area. It does not fit well into our common lithologic terms. It is calcareous with much finely divided silica, and probably contains some clay. The siliceous punky residue left after leaching of the lime certainly is not a "sandstone."—F. M. S.

A. Thin-bedded soft Shriver sandstone; continuous with B. North base of small west knob in north environs of Tyrone. Looking south.

B. Ridgeley sandstone in continuous exposure on the right (west) with the Shriver sandstone shown in A.

of weathering. This, and the weak nature of the rock coupled with the unconsolidated valley fill, combine to make exposures in the northwestern area few and poor.

In Warrior Ridge and the nearby hills in the southeast corner of the quadrangle, approximately flat-lying Ridgeley beds appear better to have resisted disintegration than the tilted ones in Bald Eagle Valley. They underlie several square miles and may be conveniently seen on the Pennsylvania Railroad north from Huntingdon along the Juniata River above the State Industrial School. Better exposures, perhaps the finest in central Pennsylvania, are those in the glass sand quarries at Mapleton, to the south in the Mount Union quadrangle.

Where observed in fresh exposures, the Ridgeley gives the impression of being extremely massive and may, at a short distance, be mistaken for limestone. It is in reality composed of heavy beds of yellowish to nearly white sandstone. Exposure rapidly reduces these beds to sand reminiscent of a recent sea beach. The pure quartz sand grains range from medium coarse to a fine conglomerate phase, and are well-rounded and sorted. Upon its qualification of purity depends its adaptability for glass manufacture. The Ridgeley formation is fully 200 feet thick in the southeast part of the Tyrone quadrangle, but may be somewhat thinner in the northwestern part. Fossils are not rare, but the friable character of the matrix renders their collecting in good condition quite difficult. *"Spirifer" arenosus* and *Rensselæria ovoides* are common.

ONONDAGA GROUP

Onondaga is another of those New York names of long-standing in the annals of the Devonian stratigraphy of the eastern United States. It has been used in Pennsylvania in only comparatively recent years, because of the prevalence of other, older, local or lithologic terms. In 1912 Kindle furnished a rather limited description of the Onondaga in Pennsylvania. Prior thereto, it had little if any recognition in this part of the State. Butts, however, clearly recognized it in 1918. In 1936 Willard reviewed and amplified our understanding of the Onondaga in Pennsylvania, and he has since decided to elevate the name to a group term.

The Onondaga group forms a very narrow band in Bald Eagle Valley, but it is doubtful if satisfactory exposures are today available. Beds probably belonging to this group have been observed in railroad cuts north of Tyrone, but the rapid weathering of the rock renders identification difficult. Butts has seen it exposed in small hills on the railroad near Grazierville 1½ miles southwest of Tyrone in the Altoona quadrangle. He also reports exposures in the Allensville (Menno) quadrangle where Willard has also observed it along Standing Stone Creek, as at Ford School. There, at a road fork, the Onondaga appears as a few feet of interbedded dark shale and limestone with characteristic fossils. Small gutter exposures have been observed along Route 22 at the State Industrial School west of Huntingdon.

The Onondaga group in the Tyrone quadrangle is dominantly very dark gray to practically black, non-fissile to sub-fissile shale which weathers to soft, spongy, olive or olive-drab material. Because of this

weathered color, the beds have sometimes been recorded as consisting of olive or green shales, obviously a misnomer. Thin beds or lenses of limestone may be, in fact usually are, present, particularly in the upper part. They are non-cherty and are correlated with the non-cherty member to the east which I. C. White called the Selinsgrove lower limestone. In the Tyrone region it is not at once obvious why the Onondaga should be designated as a group, but in other parts of Pennsylvania, particularly to the east in the Susquehanna Valley and beyond, it is resolved into several formations and lesser units. The Onondaga is readily separated from the underlying Oriskany sandstone (Ridgeley formation). No contact is recorded in the Tyrone quadrangle, but on the Pennsylvania Railroad at Newton Hamilton the relations are beautifully exposed and are clearly disconformable. Only on its fauna can the Onondaga be surely and readily separated in central and southcentral Pennsylvania from the overlying Marcellus black shale because the Marcellus and Onondaga are lithologically so similar in fresh cuts and both may carry thin limestone beds. Butts has identified the following fauna from the Onondaga at Grazierville and other points to the southwest, and Willard has found similar assemblies to the north and south of the Tyrone quadrangle:

Anoplotheca acutiplicata
Odontocephalus aegeria
Phacops rana
P. cristata
Bollia ungula
Octonaria stigmata
Loxonema sp.

Although no good suites of fossils have been found in the Onondaga of the Tyrone quadrangle, the above are distinctive of the group and should serve to identify it to future students to whom it may be exposed and who may wish to separate it from the Marcellus.

HAMILTON GROUP[17]

During the last eight or nine years the Middle Devonian has been extensively reviewed in Pennsylvania, chiefly through the studies of Willard and Cleaves. Particularly attention has been devoted to the post-Onondaga beds which are now, after the present New York practice in the type region, thrown together as the Hamilton group (cf. G. A. Cooper). Throughout central Pennsylvania the Hamilton group is divisible into two units of formational rank, thus:

Mahantango formation
Marcellus formation

In the Tyrone Quadrangle, these are recognized, and their outcrops are confined to the southeast and northwest corners. Not until Butts mapped this region and Willard worked out the Hamilton group along the Allegheny Front, was an accurate knowledge of the Middle Devonian in this area known. Instead, reliance had to be placed upon the Second Pennsylvania Geological Survey's county maps as our chief source of information. In the work of the Second Survey, the lament-

[17] The use of Hamilton group here follows that now adopted by the Pennsylvania Topographic and Geologic Survey and is in agreement with the latest use in New York. This is not, however, in agreement with Dr. Butts's original description of the Tyrone quadrangle in which he preferred the older terminology of Hamilton formation above and Marcellus formation below.

able error was perpetrated of confusing, in Bald Eagle Valley, the "Genesee" (Burket) and the Marcellus black shales and the Tully, Onondaga and Helderberg limestones. As all of these units possess distinctive fossils, they are readily separable.

The basal Marcellus is separated from the Onondaga largely upon faunal evidence. In this part of the State there is no proof known of a stratigraphic break between the two. The top of the Hamilton group, that is, the highest beds of the Mahantango shale, is more readily distinguished from the overlying basal Portage beds. Usually, the highest Hamilton strata carry in central and eastern Pennsylvania a fossiliferous zone with *Vitulina pustulosa* common. Such has not been found in the Tyrone Quadrangle, perhaps because of lack of good exposures, since it is known in the general region to the east. There is, however, a complementary lithologic change which is recognized at the top of the Hamilton group.

Marcellus formation. The lower part of the Hamilton group in Pennsylvania is the well-known and long-recognized Marcellus black shale. It is perhaps the most persistent Paleozoic unit in the State. In the Tyrone quadrangle the Marcellus is found in areas adjacent to those occupied by the Mahantango formation. It is poorly exposed in Bald Eagle Creek Valley, and only a narrow band crosses the extreme southwestern corner of the sheet. Butts observed it at Grazierville in the Altoona quadrangle, and, like the Mahantango, it is well exposed about the town of Huntingdon, as on the campus of Juniata College, and along Route 22 opposite the State Industrial School. This latter exposure is of interest in that it shows some thin, interbedded, fossiliferous limestones among the shale.

Except for these limestone lenses or bands of limestone nodules, the Marcellus in this part of the State is dominantly fissile, black shale devoid of sandstone. The shale on exposure may bleach to light-gray or nearly white. Its thickness ranges from 150 to 200 feet. The limestone and occasional fossils differentiate it from the Burket black shale of the Portage group with which it has been sometimes confused. Though sparingly fossiliferous, occasionally fairly abundant faunules are found. They are seldom particularly diversified. Such a one was collected by Willard in a road cut ½ mile southwest from Vail:

Lithistid sponge?
Crinoidea, columnals
Orbiculoidea lodiensis var. *media*
Chonetes coronatus
C. vicinus ?
C. sp.
Liorhynchus limitare
Ambocoelia umbonata
Styliolina fissurella

To this list may be added *Strophalosia truncata* and *Buchiola* which were collected by Butts in the quadrangle.

Mahantango formation. Finding the post-Marcellus portion of the Hamilton group of central Pennsylvania indivisible into widespread components, Willard introduced (1935) the name Mahantango formation from Mahantango Creek in Snyder and Juniata counties, Pennsylvania. This has been applied over the entire central and south-

central region of Middle Devonian outcrops in the State, embracing therein the Tyrone quadrangle. The term Mahantango is essentially equal to the name "Hamilton" as used by most earlier writers. The formation is usually about 1,200 feet thick, thickening somewhat to the south and ranging between 1,000 and 1,200 feet in the Tyrone quadrangle. In the northwest corner it probably is the principal bedrock of Bald Eagle Creek Valley, and it may be there seen at a few places, chiefly in cuts along U. S. Route 220 between Big Fill Run and Dix. It is also exposed near Bald Eagle railroad station and between Tyrone and Altoona. A narrow band just crosses the southeastern corner of the quadrangle and its full thickness crops out along the valley for miles southwest of Huntingdon. There are good exposures along the streets in the eastern environs of Huntingdon.

The Mahantango formation is of nearly uniform lithology. Occasionally sandstones occur, but, except in Bedford County and in the Susquehanna-Juniata valleys north from Harrisburg, these are probably all thin and may be merely lenses. Thus, a few relatively heavy sandstone beds are recognized in the Huntingdon Quadrangle, but they appear to be absent in the Tyrone region, or are so attenuated as not to be recognized as such. The dominant lithology is, therefore, uniform dark-brown or gray shale which varies from clayey to finely arenaceous. It may weather to chips, splinters or irregular blocks. There is little color change on weathering, save for fading, but spheroidal forms often develop. No true limestone is known in this formation in the Tyrone quadrangle, although beds of shells, coquinites, may occur which approximate limestone.

Butts has collected a large fauna from his "Hamilton" (Mahantango) shales at Altoona. Willard has published lists of his collection from near Huntingdon and other neighboring localities. No such large collection has been secured in the Tyrone quadrangle, but Willard found in a highway cut on the west side of Bald Eagle Creek, ½ mile southwest of Vail, the following:

Crinoidea, columnals
Chonetes sp.
Tropidoleptus carinatus
"Spirifer" mucronatus
Nucula bellistriata
Tentaculites bellulus
Homalonotus dekayi
Taonurus sp.

PORTAGE GROUP

The Hamilton group in Pennsylvania is overlain by the Portage group assigned to the lower part of the Upper Devonian. Several units are recognized, and some of these were first studied and named by Butts in the Altoona region. The maximum thickness of the group is close to 2,000 feet, divided as follows:

Brallier shale
Harrell shale
Burket shale
Tully limestone

This is the sequence typical of the region along the Allegheny Front, and it is present in the Tyrone quadrangle save that unquestionable Tully has never been found within the boundaries of the area. The

Portage group is exposed only in the northwestern corner of the quadrangle which it crosses in a broad, southwestward-trending band northwest of Bald Eagle Creek. It underlies the west slope of the valley of that stream.

Tully limestone. No Tully has been absolutely identified in the Tyrone quadrangle, but it deserves mention because of the very reasonable certainty that it underlies the unconsolidated débris of Bald Eagle Valley. Fifteen miles south of Altoona, about 2 miles southwest of Claysburg, and ½ mile southeast of Cove in the Huntingdon Quadrangle, Butts found one foot of this limestone, and Willard observed it to increase to nearly 200 feet in the region of Lock Haven. If found in the quadrangle, it should consist of fairly massive, gray limestone and may be expected to carry a distinctive fauna such as the following which was collected at the locality southwest of Claysburg:

Crinoidea, columnals
Stictopora sp.
Chonetes coronatus
C. aurora
C. sp. nov. near *lepidus*
C. sp.
"*Spirifer*" *mucronatus*
"*S.*" *tullius*
Echinocoelia ambocoelioides
Hypothyridina venustula
Emanuella pennsylvanica
Pleurotomaria capillaria
Styliolina fissurella
Phacops sp.

Burket shale. Butts introduced the term Burket for the black shale at the base of the Harrell gray shale in the Altoona region. He included it as a member or variety of the latter. Willard's recent studies of the Portage group in Pennsylvania have shown that this black shale has a wide distribution eastward over the State and may occur where the Harrell is absent or poorly developed. Therefore, the Burket is separated from the Harrell and handled as a distinct unit. It is the "Genesee" of the earlier writers on the geology of Pennsylvania, Maryland, and Virginia and perhaps equals the Geneseo of New York.[18]

Fully 75 feet of the fissile, black, non-calcareous, non-arenaceous Burket shale appears to fringe the western side of Bald Eagle Valley, where it has been seen in road cuts along the highway and on a secondary road 1,000 feet northwest of Dix. Fossils are rare in the Burket. *Styliolina fissurella* and examples of *Buchiola* can usually be found plus occasional other Naples forms, mostly tiny pelecypods, such as *Paracardium doris.*

Harrell shale. (restricted). Below the Brallier greenish shale, the next older unit of the Portage group is the Harrell gray shale. Butts is responsible for its naming from the type locality, Harrell Station on the Pennsylvania Railroad in the Hollidaysburg quadrangle. The rock is relatively soft, gray, non-arenaceous shale in the Tyrone

[18] The following interesting correlation suggested by Dr. Butts is appended: "The Burket carries a distinctive Naples fauna as does the overlying gray shale of the Harrell. No occurrence of *Schizobolus truncatus,* a characteristic fossil of the Genesee, is known, but *Paracardium doris* a common fossil of the Naples but not reported from the Genesee, is common in the Burket. The probability therefore, is that the Burket is not Genesee. On lithologic as well as on paleontologic grounds it can more probably be correlated with the Middlesex black shale of the Genesee Valley as near Mount Morris, Livingston County, N. Y. The Middlesex is a densely black, fissile shale 32 feet thick and lithologically is more like the Burket than is the Genesee which is only about one-third black shale, the remainder being gray shale."

quadrangle, occurring only along the base of the hills which border the west side of Bald Eagle Valley. Exposures are poor due to its softness. The thickness is supposed to range from 150 to 200 feet thick according to measurements by Butts. No fossils were obtained from the Harrell shale in the quadrangle, but it nevertheless often carries an abundant Naples fauna. Such is illustrated by the following faunule collected by Willard from an exposure at Huntingdon. Butts suggest that lithologically and paleontologically the Harrell (restricted) may be correlated with the Cashaqua shale of the Genesee Valley of New York.

Pterochaneia fragilis
Paracardium doris
Actinopteria (?)
Pelecypoda, indet.
Styliolina fissurella
Batrites aciculum
Probeloceras lutheri
Plant fragments

Brallier shale. The highest Portage unit and the dominant element of this group is the Brallier shale, which is 1,000 to 1,800 feet thick in the Tyrone quadrangle. Butts named it for Brallier Station on the Broad Top Mountain and Huntingdon Railroad, five miles north of Everett, Pennsylvania. It crosses the Tyrone quadrangle in a broad belt of hilly country adjacent to Bald Eagle Valley on its northwest side. It underlies the lower foot-hills of the Allegheny Mountain, so that exposures are common along the numerous tributary streams that enter Bald Eagle Creek from the northwest. The base of the Brallier is separated from the Harrell only by transitional beds, but the dark gray color and relatively abundant fossils of the Harrell distinguish it from the Brallier. The Brallier is itself light- to dark-green and nearly barren. It may be finely arenaceous and micaceous. The beds are commonly finely laminated and split apart on the bedding planes in extraordinarily smooth faces not unlike slate. Weathered, the rock produces more or less irregular pieces, the thinnest of which are much thicker than ordinary clay shale. A characteristic feature of some of the thin laminæ is their dimpled surfaces often glistening with abundant, minute mica flakes. Occasional, thin sandstones as beds or lenses are scattered through the shale. These are significant on comparison of the Brallier on the Allegheny Front with the Portage of eastern Pennsylvania where the shale passes laterally over into the contemporaneously deposited Trimmers Rock sandstone of equal thickness and carrying a numerous, well-established Ithaca fauna. The stray sandstones in the Tyrone quadrangle and along the Allegheny Front in central Pennsylvania are thought to represent intercalations of the Trimmers Rock sandstone, especially as they carry occasional Ithaca forms, not found elsewhere in the Brallier shale. None of these fossiliferous sandstones was observed in the Tyrone quadrangle, but along the railroad west from Duncansville, about 1 mile northwest of Newry, which lies southwest of Tyrone, such an interbedded sandstone carried:

Crinoidea, columnals
Lingula sp.
Productella lachrymosa
Camarotoechia sp.
Liorhynchus mesacostale
Pugnax pugnus var. *altus*
"*Spirifer*" *mesacostalis*
Coelospira sp. nov.
Plantae, carbonized fragments
Fucoids undetermined

In contrast to this, the true Brallier shale is almost barren. Very rarely a Naples fossil as *Buchiola retrostriata* and a few others, turns up. The only really common form is a peculiar trail, *Pteridichnites biseriatus* first described by Clarke and Swartz from the Portage shales of Maryland. Butts remarks that it is common also in the Brallier in Virginia as far south as Hot Springs, Bath County. With it are numerous shreds of vegetation and sometimes an example of *Fucoides graphica*. The top of the Brallier is marked by the change from the typical shale to sandy beds with "*Spirifer disjunctus*, indicating the commencement of Chemung deposition.*

CHEMUNG GROUP

The highest marine Devonian strata in northwestern Pennsylvania, the Chautauquan stage, which is next younger than the Portage, is divided thus:

Conewango group
Conneaut group
Canadaway group
Chemung group

Only the Chemung is recognized as such along the Allegheny Front, the other groups being confined to the northwestern and northcentral counties. Rather, on the Allegheny Front, all post-Chemung Devonian appears to be dominated by the continental facies, the Catskill red beds, discussed in the next section. Butts has recognized certain fossils in marine interbeds in the Catskill which may be of Canadaway age or later. Of these, cognizance will be taken in describing the Catskill.

The use of the name Chemung as a group term actually has little application as far south as Tyrone. In northcentral Pennsylvania, it is, after the New York method, split into:

Wellsburg formation
Cayuta formation

At the top there is present in places the Fall Creek conglomerate, not known on the "Front." Evidence for subdividing the Chemung has been recognized by Willard only as far south as Lock Haven. Beyond that point there are neither faunal nor stratigraphic means for adequate subdivision. However, the term Chemung group is here retained for convenience and uniformity with recognized usage elsewhere in Pennsylvania. It may be noted incidentally, that in Maryland the Chemung has been designated as the upper member of the Jennings formation, and as such it was divided:

Upper shale and sandstone beds
Upper conglomerate
Middle shale and sandstone beds
Lower conglomerate
Lower shale and sandstone beds

* The Brallier and Trimmers Rock seem evidently to be complementary facies of the same general stratigraphic unit. It is of interest to point out that elements of the Ithaca fauna as "*Spirifer*" *mucronatus posterus* and *Leiorhynchus globuliforme* occur in the most southeastern belts of the Brallier west of Winchester, Frederick County, Va. —Butts.

All of these carry Chemung fossils. The only evidence for later marine Devonian in Maryland is found at Allegany Grove, where the dominantly Chemung fauna has a few elements which suggest a slightly younger age. The significance of this will appear as this discussion continues. [19]

In the Tyrone quadrangle, the Chemung is restricted areally to a band about 1 mile wide which crosses the northwestern corner. This is a region of low hills lying almost under the Allegheny Front escarpment, from which it is separated by a band of red Catskill sediments. Many exposures are to be observed, chiefly along the valleys of brooks transverse to the strike. Lithologically, the Chemung is dominated by gray to greenish-gray sandstones which interbed with gray shale and greenish mudrock. The sandstones commonly have a lumpy or gnarled aspect. Micaceous surfaces and ripple marks are common. The bedding varies from flaggy to massive. Toward the top of the Chemung, the strata assume a chocolate or plum color as the passage into the Catskill facies is approached. It is important that this change be not confused with the "pink rock" of well drillers in northwestern Pennsylvania. There, it is usually to be assigned to the *Chadokoin*, which is of late Conneaut age. Actually, this unusual color develops near the transition between marine and non-marine beds all across Pennsylvania and may range in age from Conneaut (or perhaps even later) down into the middle Portage. Throughout, these beds of Chemung age are commonly quite fossiliferous. There is little differentiation among the faunules. *"Spirifer" disjunctus* is universally present, and the lowest beds commonly are replete with *Ambocoelia umbonata ("gregara")*. Although no extensive collections were obtained from the Chemung in the Tyrone quadrangle, plentiful examples of the fauna were secured in Blair County. The following faunule is characteristic of the Chemung in this region, and was taken on the railroad west of Duncansville:

Crinoidea, columnals
Stropheodonta maynardi
Leptostrophia perplana var. *nervosa*
L. interstrialis
Douvillina cayuta
D. tioga
Schellwienella (Schuchertella) chemungensis
Schizophoria striatula
Productella lachrymosa
Camarotoechia horsfordi
Atrypa hystrix
"Spirifer" mesastrialis
"S." mesacostalis
"S." disjunctus
"S." sp.
Ambocoelia umbonata
Actinopteria?
Leptodesma sp.
Pelecypod, indet.
Tentaculites descissus
Plantae, carbonized stems.

[19] The use of Chemung as a group term including two or more formations follows the most recently proposed subdivisions of the higher, marine Devonian (post-Portage) in northwestern Pennsylvania. Although Dr. Butts has not accepted these new groups, they are applied here in conformity with the terminology adopted by the Pennsylvania Topographic and Geologic Survey. The highest marine Devonian (post-Portage) along the Allegheny Front in the latitude of Tyrone is doubtless all pre-Canadaway, so that in mapping it as Chemung it agrees with the recent usage cited and at the same time does no violence to Dr. Butts's objection to the use of the terms Canadaway, Conneaut and Conewango, because these evidently do not apply directly to the area. Dr. Butts also objects to the use of the term Catskill, and personally recommends the revival of the name Hampshire to be applied to the continental Devonian in the Tyrone quadrangle. Here again, we are following the latest use of Catskill by the State Survey in which it is applied to all continental Devonian beds of whatever age. This usage is also now recognized in New York (personal communication from Dr. Winifred Goldring) and is generally accepted by most workers in the Devonian in New York and Pennsylvania (See recent work by Caster, Cooper, Willard, etc.).

The Portage-Chemung contact, as noted already, is not sharp. The sandstones come in, rather abruptly to be sure, but Brallier-like shale may continue even after Chemung fossils appear. Our safest criterion for differentiation is faunal. The first appearance of *"Spirifer" disjunctus* is taken to mark the base of the Chemung, and serves to distinguish faunas which otherwise might be mistaken for Ithaca. It should be reiterated, too, that *Ambocoelia umbonata* is often particularly abundant at the base of the Chemung.

The Chemung beds are about 2,500 feet thick in the Tyrone quadrangle. Near the middle of the group there occurs a massive white-quartz sandstone which is commonly pebbly and may be locally a true conglomerate. Conglomeratic beds of this sort are not uncommon in the Chemung in southcentral Pennsylvania, and presumably they may tie in with similar beds in Maryland after the sequence quoted for that State. Locally, they produce small ridges or hills. Although I. C. White was inclined to accentuate their importance, particularly his Alligrippus conglomerate, present-day observation and practice indicate that they are local lenses rather than far-flung key beds. Butts has observed that the uppermost 50 feet of the Chemung may be "coarse, yellow-green, fossiliferous shale or mudrock."

CATSKILL CONTINENTAL FACIES

The term Catskill is here used exclusively as a facies designation. This usage has been adopted by the Pennsylvania Topographic and Geologic Survey workers in the Devonian. It is applied to all Devonian continental facies sediments of whatever specific age. In this it may be compared to chronologically equivalent marine formations or groups. The lateral passage from the one to the other can hardly be appreciated in so limited an area as a single quadrangle, but over wide areas is readily seen. Thus, if one follows the marine Chemung and Portage groups eastward across Pennsylvania they may be seen to be gradually displaced downward by the encroaching continental Catskill facies. Actually, the marine units are as truly facies as is the Catskill. The Catskill facies extends across northern Pennsylvania from the upper Delaware Valley to the region of Warren, and is encountered all along the Allegheny Front. It represents progressive off-lap and concomitant displacement westward of contemporaneous marine strata. That this was a progressive movement has been demonstrated by Willard. In northcentral New Jersey, the lowest red beds are of Hamilton age. In the upper Delaware Valley, they belong to the middle Portage. Along the Susquehanna-Juniata valleys north of Harrisburg, the highest marine beds beneath the first red are of very early Chemung age. At the Allegheny Front from Lock Haven to the Maryland line, the Catskill facies commences to displace the marine at or very near the close of the Chemung. Progressively younger displacements are found from Bradford County west along our northern boundary, but to the south this phase of the off-lap is concealed west of the "Front." Thus, the age of the base of the Catskill on the Allegheny Front and so in the Tioga quadrangle may be placed as late Chemung.

There is at least 2,500 feet of Catskill in the Tyrone quadrangle, confined here to a single band 1¼ to 1½ miles wide in the extreme northwestern corner of the quadrangle where the Catskill forms the hilly belt at the foot of the Allegheny escarpment, rising some distance up the slope to be capped by the massive, gray sandstones and conglomerates of the Pocono of early Mississippian age. The Catskill may be observed on the Tyrone and Clearfield branch of the Pennsylvania Railroad up the valley of Vanscoyoc Run and in other parallel valleys. None of these compare with those of the Horseshoe Curve section on the Pennsylvania Railroad's main-line above Altoona. Throughout the belt underlain by the Catskill, red soil colors prevail, for the Catskill is dominated by red sandstone and shale. The shale is often non-fissile, mudrock which yields chunks, not flakes. The sandstones are less abundant than the shale or mudrock, but because of their hardness are more conspicuous in exposures. Mud cracks and ripple-marked surfaces occur. Among the red beds are gray or gray-green sandstones and shales. Butts estimates that these make up 20 percent of the total thickness. Occasionally, these non-red layers in the Catskill carry sparse remnants of marine faunas, particularly in the lower portion where we may imagine the displacement of the Chemung or later marine facies to have been incompletely attained. Such a fossiliferous bed of white sandstone was found by Butts "at the head of Near-hoof Hollow just north of Mountain Orchard School, 3¼ miles north of the railroad station at Tyrone." It is low in the Catskill, and the fossils he identified from it are *Schuchertella chemungensis*, "*Spirifer*" *disjunctus*, *Pterinea* sp.

No other fossils other than fragments of fish plates or bits of vegetation are known from the Catskill of the Tyrone quadrangle. However, it is worth mentioning here because of its significance in indicating the age of these red strata, what Butts has found on the Horseshoe Curve. There, about 2 miles east of Kittanning Point, he collected a few fossils:

Grammysia elliptica (pre- to post-Chemung)
Leptodesma umbonata (Conneaut)
Pteronites rostatus (Canadaway)
Schizodus chemungensis (?) (pre- to post-Chemung)

In listing the above, their ranges have been parenthetically supplied according to Chadwick's notations. If correctly identified, it appears that this meager fauna implies beds of somewhat younger age than Chemung, but the association of the Conneaut with Canadaway form is puzzling. Somewhat higher up, Butts reported among "a few other poorly preserved and undeterminable fossils" the following:

Sphenotus clavulus (Canadaway and later)
Orthoceras sp.

He recorded also *Oehlertella pleurites* at the top of the Chemung or just below the Catskill. The range of the pelecypod as listed by Chadwick again indicates comparatively late Devonian. Considering the uncertainty of preservation of most of this material, the fossils in general are of rather dubious value for more than general correlative or chronologic purposes. Inarticulate brachiopods are such notoriously

poor guide fossils, that it is inadvisable seriously to reckon the *Oehlertella* heavily. The fossils are late Devonian, not early Mississippian in age. This is supported by stratigraphic evidence. They are all found in the red beds well below the basal Pocono of early Mississippian age. This agrees with Willard's findings of some years ago which placed the base of the red beds on the "Front" at or near the top of the Chemung. Willard, from his studies of the Catskill facies in Pennsylvania, suggested more recently that the top of this facies on the Allegheny Front might be tied in with the Oswayo of north-central Pennsylvania, and thence with the Elk Mountain sandstone of our northeastern Catskill. As such it is very late Devonian in age, but is separated from the overlying beds of Mississippian age (the Pocono) by an hiatus, here unrecognizable clearly, but equivalent to the Mount Pleasant red beds of northeastern Pennsylvania.

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CARBONIFEROUS SYSTEM

Mississippian series

POCONO FORMATION

The Pocono formation was named from the Pocono Mountains in Monroe County, eastern Pennsylvania.

The only area underlain by the Pocono in the Tyrone quadrangle is about 1½ square miles in the northwest corner where it crops out on the steep scarp of the Allegheny Front from the altitude of 1,600 feet to the summit of Allegheny Mountain at 2,360 feet above sea level. As usual along the outcrop on the Allegheny Front across Pennsylvania only small patches of the formation are exposed here and there. The most complete knowledge of the Pocono has been obtained from the exposures in the cuts on the main line of the Pennsylvania Railroad southwest of Altoona between Kittanning Point and the tunnel at Gallitzin. The lower part of the Pocono and the upper part of the underlying Catskill including the contact are extensively exposed along the Pennsylvania Railroad on the West Branch of the Susquehanna River between Queens Run a few miles northwest of Lock Haven and Emporium in Cameron County.

As shown on the Pennsylvania Railroad east of Gallitzin the Pocono is composed of two distinct parts—the lower of shale, gray and red, and sandstone, and the upper of sandstone. [17]

The lower part begins with a stratum of coarse-grained gray sandstone 180 feet thick immediately succeeding the red shale at the top of the underlying Catskill. Above this sandstone is about 500 feet of alternating shale and sandstone and a thin layer or so of clay. The shale is mostly gray and more or less sandy, but there is an occasional red layer. The sandstone likewise is mostly gray, but there are a few red layers. A few small exposures of the gray shale and thin-bedded gray sandstone of this part of the formation were noted along an old dug road on the escarpment just north of Gardner in the Tyrone quadrangle.

Burgoon sandstone member.—The upper part of the Pocono is composed almost entirely of rather thick-bedded greenish-gray sandstone, almost all of which is shown in the Pennsylvania Railroad section east of Gallitzin already mentioned. It is named the Burgoon sandstone member of the Pocono from Burgoon Run west of the station at Kittanning Point, the stream crossed by the famous Horseshoe Curve on the Pennsylvania Railroad.

[17] Butts, Charles, U. S. Geol. Survey Geol. Atlas, Ebensburg folio (No. 133), p. 3, 1905.

The lower 100 feet of the Burgoon member caps the summit of the hill in the extreme northwest corner of the Tyrone quadrangle. Here, as farther northeast in the Bellefonte quadrangle, the basal 30 feet is rather coarse conglomerate composed of quartz pebbles in a matrix of quartz sand. Large blocks of this conglomerate creeping down the steep scarp are conspicuously visible from below when the leaves are off the trees.

The Burgoon, as measured on the railroad east of Gallitzin, is 300 feet thick, and the entire thickness of the Pocono is about 1,000 feet.

The Pocono of central Pennsylvania below the Burgoon sandstone has a few plant remains and fewer invertebrate fossils. Among the plants, as identified by David White, is a species of *Rachopteris*, *Lepidodendron chemungense*?, *L. corrugatum* (*Eskdalia*?), *L. corrugatum* var. *approximatum*, *L. scobiniforme*, *Sphenopteris* cf. *S. vespertina*. The invertebrates are *Lingula* cf. *L. gannensis* and a pelecypod resembling *Mytilarca*. The Lepidodendrons, except possibly *L. chemungense*?, are Mississippian; so is the *Lingula*. The Pocono therefore is correlated with the Price sandstone of Virginia, which also contains *Lepidodendron scobiniforme* common, and an invertebrate fauna definitely correlating it with the Cuyahoga group of Ohio. The Burgoon sandstone is correlated with the Big Injun sand of the oil well drillers and with the Logan formation of Ohio.

QUATERNARY SYSTEM

TERRACE GRAVELS

Ancient stream gravels occur at two distinct levels in the Tyrone area and surrounding country. The higher level and older gravel lies at an altitude of 1,050 feet above sea level. The gravel is all quartz or quartzite and the pebbles small. There is a small remnant of such gravel (not mapped) on the slope half a mile directly south of Ribot or a little more than a mile northeast of Petersburg, and a larger area at about the same altitude on the ridge directly north of Huntingdon in the southeast corner of the quadrangle. Here some cobbles are of quartzite and six inches in diameter, but most of them are not more than two inches. These deposits are 350 to 400 feet above the present level of the Juniata River.

Scattered pebbles in considerable numbers (not mapped) occur at the 950-foot level on the point of the spur about ½ mile slightly southwest of Spruce Creek.

The most notable of these deposits, however, are at the level of about 750 to 800 feet. One such deposit is just above (north of) the highway about 1 mile west of Petersburg, and the largest area is on the spur projecting into the loop of the Frankstown Branch of the Juniata for a mile or so southeast of Alexandria. These deposits contain well worn boulders as much as one foot in diameter and scarcely water-worn blocks of Tuscarora quartzite several feet in area and a foot or more thick. The highest deposits of this general level are nearly 100 feet above present river level.

The age of the terrace gravels at 150 to 400 feet above the present streams is indicated by the amount of down cutting of the Juniata since their deposition. Presumably the deposits are late Tertiary or early Pleistocene. The lower terrace deposits are probably of late

Pleistocene age, and it seems reasonable to believe that they were deposited in the Wisconsin or latest stage of the Glacial period.

ALLUVIUM

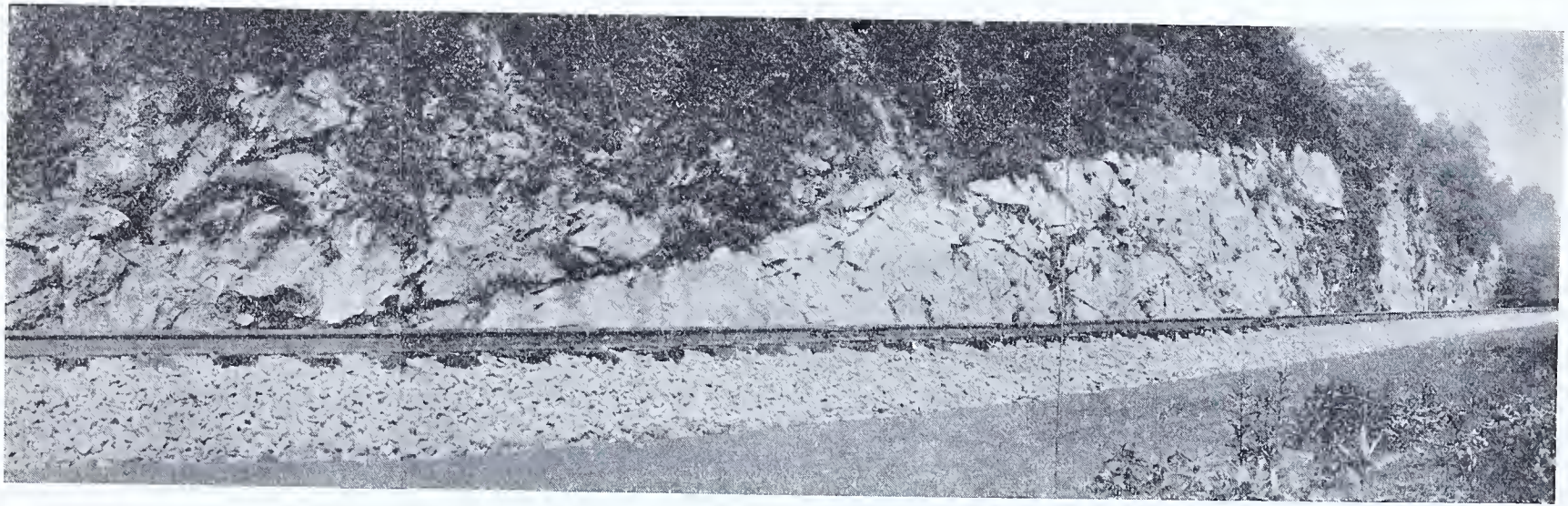
Alluvium includes the clay, sand, and gravel of the modern flood plains or alluvial flats of the streams. These materials have been recently deposited by the streams as they have overflowed their banks. The largest areas of alluvium are along the rivers and creeks in the southeast quarter of the quadrangle and in Bald Eagle Valley. The alluvium of Bald Eagle Valley contains many boulders of quartzite from Bald Eagle Mountain.

The thickness of the alluvium can not be stated but is judged not to be very great since bedrock is locally exposed in the streams.

STRUCTURES

The Tyrone quadrangle is located upon the summit and flanks of the Nittany arch, which is a great upbending fold of the strata trending northeast, about 35 miles wide and 80 miles between ends of the maximum uplift. If the youngest formations, of Pennsylvanian age, in the bordering synclines on the northwest and southeast were projected across the arch, or restored in imagination, its summit would be more than 5 miles above sea level and make a mountain comparable to Mount Everest in elevation. As shown by the map, within the Tyrone quadrangle the arch curves to a more northeasterly course north of the Juniata River. This may indicate maximum intensity of pressure across that area in the vicinity of the river with resulting torsional effects which may explain the rather greater complexity of the faulting and minor folding of that transverse belt. In cross section the Nittany arch is not an evenly curving structure, but its profile is somewhat broken by faults and undulations through minor folds superposed upon the major structure. In other words it is an anticlinorium of moderately complex composition. As details are sufficiently shown by the geologic structure sections only the more important features will be discussed here.

Sinking Valley anticline.—The apex of the Nittany arch in this quadrangle is along the Sinking Valley anticline between Birmingham and Warriorsmark where the oldest formation of the quadrangle, the Warrior limestone of Upper Cambrian age, crops out. The northwest limb of this anticline appears to have been extinguished in the development of the Birmingham fault for a short distance northeast of Warriorsmark, but it comes in again 1 mile or so north of the quadrangle where the Sinking Valley anticline merges into the northwest limb of the Gatesburg anticline, which continues northeast as the main axis of the Nittany arch. The narrow elongate area of Warrior limestone in the Bellefonte quadrangle along and just southeast of the headwaters of Buffalo Run 5 miles northeast of Gatesburg are on the continuation of the Sinking Valley anticline. From the axis of this anticline the strata dip continuously northwest and, with interruptions, to the southeast. The northwest dip increases from the axis toward Bald Eagle Mountain until the dip is vertical and in places overturned, then northwest of Bald Eagle Valley gradually diminishes



The Birmingham overthrust fault. The dark overthrust block is upper Warrior limestone or basal Gatesburg formation. The overridden limestone, white, is Carlim overturned and dipping southeast about 40°. The dip of the fault plane is about 15° southeast, and the stratigraphic displacement is estimated to be about 5,000 feet. Main line of the Pennsylvania Railroad about 2,000 feet southeast of Birmingham railroad station. Looking about west. This is probably the best exposure of an overthrust fault in the Appalachian Valley. Photographed in 1913.

to 5 to 10° northwest at the Allegheny Front in the extreme northwest corner of the quadrangle. The overturned dip to the extreme of 25 or 30° southeast in the Bellefonte dolomite may be seen at the eastern end of Ironville. (See section GG′.) Southeast dips of 40° in the Juniata formation are exhibited in the Tyrone Gap.

The Nittany arch thus conforms to the general rule of asymmetry characterizing the Appalachian folding generally. This feature is well illustrated by sections BB′, DD′, EE′, and GG′ of the structure section sheet. The much steeper dip on the northwest flanks of the anticlines is such as would result from folding of the originally horizontal strata by pressure applied on the southeast. Southeast of the Scotch Valley axis the strata dip in general southeastward but with several interruptions by faults and folds. Among the notable folds are the Round Mountain and Leading Ridge anticlines by which the outcrop of the Tuscarora quartzite is twice repeated southeast of its main outcrop along Tussey Mountain. Notable, too, is the very striking en echelon folding in the weaker Silurian formations in the area between Tussey Mountain and Leading Ridge on the northwest and the scarp of the uplands in the southeast corner of the quadrangle. Here is shown the different responses of weaker rocks to compressive forces from that shown by the stronger rocks on the summit of the Nittany arch.

Scotch Valley.—Attention may be called to the peculiar and striking structural feature known as Scotch Valley in the northeast corner of the Hollidaysburg quadrangle which extends into the southwest corner of the Tyrone quadrangle as Canoe Valley. In the Hollidaysburg quadrangle this may be likened to a great dent in the northwest limb of the Nittany arch made by a crushing blow. This syncline extends northeast into the Tyrone area as far as Huntingdon Furnace and may be continuous with the shallow Marengo syncline which, in the Bellefonte quadrangle to the northeast, dies out on the northwest flank of the Gatesburg anticline.

Birmingham fault.—One of the most interesting structural features is the Birmingham fault and associated minor stratigraphic dislocations. This is fortunately exposed in the railroad cut next southeast of the railroad station at Birmingham as shown in Plate 14. As in the Appalachian thrusts generally, the movement is northwest and the fault plane dips southeast at the low angle of 15 degrees. The stratigraphic displacement is about 5,000 feet, the lower part of the Gatesburg dolomite, dipping parallel with the fault plane, having been thrust over the Carlim and Lowville limestones, which are overturned and dip 40° southeast. If the dip of the fault plane should persist at 15 degrees this would involve a horizontal displacement of nearly 4 miles. Immediately northwest of the fault at Birmingham is an overturned fragment of the Carlim to Tuscarora sequence, shreds of each of the units of that sequence having been strangely preserved and faulted downward on the northwest so that the overturned Tuscarora quartzite on the northwest side of the block and in turn each lower unit eastward is in contact at depth with dolomite of undetermined age in a fault block. This may be the Bellefonte dolomite. The

relation is shown in section GG′. This interpretation involves the complete crushing out of the southeast limb of an overturned anticline between Tyrone and Birmingham and the survival of a fragment of the overturned northwest limb of a second anticline lying southeast of Birmingham. It involves also a horizontal movement from the southeast in the overturned folding and faulting that seems entirely out of harmony with the southwest extension of the fault and overturned folds, all of which appear to die out, so far as existing conditions indicate, 3 or 4 miles southwest of Birmingham. The surface facts are as shown on the map and on the profile of section GG′, and the underground relations are confidently believed to be as shown, but no fully satisfactory explanation of the entire situation has as yet been reached. An alternative interpretation of the structure at Birmingham is shown in Figure 4.

The Water Street fault is of special interest because, contrary to the general rule, it is downthrown on the east. Some of the minor faults seem to be likewise characterized.

Minor faults.—The number of minor strike faults along the Juniata River and the dip fault offsetting Bald Eagle Mountain between Tyrone and Bald Eagle are probably genetically connected with the torsion involved in the change of strike that takes place in a transverse belt a few miles wide in that part of the quadrangle. Another feature connected with the faulting is the small area of Gatesburg formation with abundant sandstone that caps the western part of the knob 2 miles north of Spruce Creek (town). The Gatesburg here overlies steeply dipping Nittany dolomite which is exposed along the road at the south end of the knob and is proven to be Nittany by fossils collected on the west side of the knob within 200 feet of the top. The Gatesburg on the knob is believed to be residual from an overthrust mass from the Gatesburg area ½ mile northwest of the knob, the movement on the intervening fault having been southeastward.

On Gensinger Run 1½ miles northeast of Birmingham the overthrust Gatesburg dolomite and Warrior limestone on the Birmingham fault have been worn through in an oval area about ¾ of a mile long and the underlying younger rocks, namely, of Reedsville age, covered by the overthrust block, exposed. Such an opening is known as a fenster, or in English, as a window.

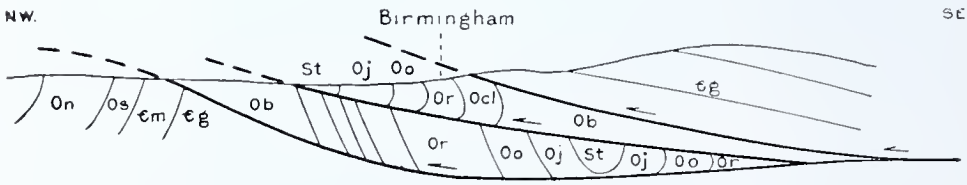


Figure 4. Cross section of structure at Birmingham, part of section GG′, 3 × enlarged, showing alternative interpretation by G. W. Stose.

GEOLOGIC HISTORY

PROTEROZOIC ERA

In the Proterozoic era stratified rocks were deposited older than the earliest rocks that contain an abundance of recognizable fossils. At the end of the era these rocks and still older ones formed one land mass in the central United States and another extending along the Atlantic coast from Newfoundland to Florida. Between the two land masses a comparatively narrow trough known as the Appalachian Strait extended from the Gulf of St. Lawrence through central Pennsylvania to the Gulf of Mexico. Proterozoic rocks formed the bottom of this strait and made the foundation upon which the overlying Paleozoic rocks in this region were deposited.

PALEOZOIC ERA

The Paleozoic era is the era of ancient life. All the great classes of invertebrate animals were already differentiated at its beginning, and the lower classes of vertebrates, the fishes and amphibia, appeared before its close.

CAMBRIAN PERIOD

In the early part of the Cambrian period coarse sediment was discharged from the bordering lands into the Appalachian Strait and formed strata of sandstone, conglomerate, and shale, in places supposed to be more than 10,000 feet thick. These rocks, now cropping out in South Mountain, Pa., and along the Blue Ridge of Virginia, are believed to extend westward in places at least and to underlie the Hollidaysburg and Huntingdon quadrangles at considerable depth.

The deposition of limestone followed and the Tomstown limestone of Pennsylvania, which is supposed to underlie the Waynesboro formation in these quadrangles and to be the equivalent of the Shady limestone of the southern Appalachians, was laid down. The deposition of this limestone indicates a change of geographic or climatic conditions, possibly a wearing down or sinking of the land, from which the slow-running streams would carry little or no sediment to the strait, or possibly a desert condition with no drainage. Again the conditions changed, and red and green mud, sand, and fine gravel were deposited, making the rocks of the Waynesboro formation. The red mud could have originated through the deep decay of the rocks of the land during Tomstown time, when there was little erosion, red sediment being commonly regarded as a result of desert conditions. Quartz pebbles in these conglomerates may have come from the Blue Ridge Mountain region, a hundred miles distant. Scarcity of life in the region is indicated by the scarcity of fossils in the Waynesboro rocks. The second change to limestone deposition in the Pleasant Hill and Warrior epochs may plausibly be associated with a period of widespread submergence of the area now the interior of the United States, during which shore lines were far removed from this region. The Pleasant Hill sea was invaded by trilobites and brachiopods near the end of this period. Precipitation of calcium carbonate from the water through the agency of bacteria or algae went on constantly. Most of the Warrior deposit,

however, is now a dolomite or magnesian limestone, possibly the product of a concentration of magnesium salts in the sea water caused by rapid evaporation.

Some of the geographic conditions at this time are indicated by the sandy layers of the Warrior. The Tyrone-Hollidaysburg-Huntingdon regions must have been near the shore of the Warrior sea, where streams carrying the sand and coarser quartz grains emptied.

Trilobites and oboloid brachiopods lived in the sea from time to time, as shown by their fossil remains found at several horizons. A species of marine alga known as *Cryptozoon*, a low plant form, was one of the principal inhabitants of the Warrior sea.

In Gatesburg time at least some parts of the land yielded great quantities of quartz sand. A somewhat arid climate may have obtained, resulting in concentrated saline water favoring the deposition of a great thickness of coarse dolomite. There may have been intermittent floods as in modern desert regions that carried the quartz sand to the sea to form the recurrent beds of sandstone.

At the beginning of Mines time the sea was invaded in places by large numbers of gastropods. The general geographic and climatic conditions of Gatesburg time continued possibly with a still wider sea and less drainage, with resulting cessation of transportation of sand but possibly with increase of disseminated silica to form the chert of the Mines. Mines conditions continued through Larke time, except that the deposits seemed to be almost without silica of any kind.

At the end of the Larke epoch it is believed that uplift of the sea bottom into dry land ensued and so remained while in the surrounding regions, including northern Huntingdon, Centre, and Franklin counties, the Stonehenge limestone, about 662 feet thick, and possibly the lower part of the Nittany dolomite were being deposited. Then the land sank, the sea again spread over it, and the deposition of the earliest unquestioned Ordovician of the region, the Nittany dolomite, began.

ORDOVICIAN PERIOD

During most of the Ordovician period, as herein defined, limestone and dolomite were deposited in this region. Near the end of the period clastic sediment that now forms the Reedsville shale was brought in.

In the Nittany epoch calcareous sediment, later becoming dolomite, was deposited; during the succeeding Axemann epoch limestone intermixed with dolomite layers was laid down; and in the Bellefonte epoch calcareous sediment that merges into dolomite was again deposited. Throughout the three epochs gastropods were the predominating forms of animal life with fewer cephalpods, brachiopods, and trilobites, and plant life in very low form was represented by cryptozoa which are supposed to be lime-secreting algae.

Following Beekmantown time is an unrecorded interval corresponding to the early part of the Chazy epoch, the rocks of which, several hundred feet thick, are absent in the region. The absent formations are the St. Peter sandstone of the Mississippi Valley and most at least of the Murfreesboro limestone, 500 feet thick, in Tennessee. The whole Appalachian Valley probably was dry land of very low relief during most of the unrecorded time.

Later, in the Carlim epoch, the sea again submerged central Pennsylvania in middle Stones River time, and in this sea the Carlim limestone was deposited.

The argillaceous Lemont limestone member of the Carlim grows thicker toward the northeast, and possibly its materials came from that quarter. Shallow water is indicated by ripple marks and mud cracks on some of the limestone layers. Bryozoa, brachiopods, pelecypods, gastropods, ostracodes, and trilobites were the principal inhabitants of the Carlim sea and were most abundant in Lemont time.

For a very long period after Carlim time the region was dry land, whereas the sea covered other parts of the Appalachian Valley, as in southwestern Virginia and eastern Tennessee, where 6,000 to 8,000 feet of strata (Blount group of Ulrich), including the Holston marble, Athens shale, Tellico sandstone, and Sevier shale, are believed to have been deposited between Carlim and Black River time but are not represented in this part of Pennsylvania.

Black River epoch.—During most of the Black River epoch much the same conditions obtained as in the Carlim epoch. In Lowville time the transgression of the Ordovician sea reached its culmination, and the region of the central United States at least was very largely submerged, for, in the eastern United States, rocks of Lowville age are probably the most widespread of any in the Ordovician system. Life was fairly abundant, especially in Rodman time, bryozoans, brachiopods, gastropods, and corals being the most common forms.

Although the deposition of limestone persisted in this region during Trenton time, it is known that terrigenous rather than calcareous sediment was being deposited in eastern Pennsylvania, where the lower part of the Martinsburg shale is of Trenton age. Some of the carbonaceous matter, to which the dark color of much of the Martinsburg shale is due, and perhaps a little of the finest clay sediment were conveyed to this region, giving the Trenton limestone its impurities and dark color. The same general forms of life inhabited the Trenton sea as were in the seas of the preceding epoch although of different species.

Reedsville epoch.—The deposition of the Reedsville shale marks the beginning of a great change in geographic conditions in the Appalachian Gulf. Uplift of the sea floor, warping, shallowing of the water, and finally a dominance of clastic sediments, more marked than had taken place in the region since early Cambrian time, are the distinguishing features of the Martinsburg, Reedsville, and succeeding epochs up to the Tonoloway. Not only in central Pennsylvania, but also over a very large part of the region of the eastern United States, the deposition of fine muds was the rule during the Reedsville epoch. The strait had probably become a broad, comparatively shallow gulf agitated by great waves and swept by tidal and possibly strong oceanic currents.

Conditions were generally favorable to life in this epoch, and at different times the sea bottom must have been covered with shell-bearing animals, for many thin layers of impure limestone composed of these shells are intercalated in the shale.

In the epoch succeeding the Reedsville there were probably lands of moderate relief on the northwest in Canada and on the southeast in the Blue Ridge province, but for a time at least they underwent relative elevation; the shores moved seaward and exposed to subaerial erosion the old submerged coastal shelf, where lay a large body of sandy residue left after the finer material of the Martinsburg shale was washed out and laid down farther seaward. This sandy shelf, now become a coastal plain and the higher land farther from the shore, supplied the sandy material of the later formations of the Ordovician.

Oswego epoch.—The deposits of the succeeding Oswego epoch are locally predominated by fine quartz sand, but become conglomeratic in parts of Pennsylvania. Willard and Cleaves (Geol. Soc. Am. Pr., 1938 meeting, *abstract)* have recorded Oswego or Bald Eagle conglomerate across Pennsylvania from the region west of Chambersburg eastward at least to Swatara Gap in northern Lebanon County. The presence of the Oswego here and in central New York indicates the possible derivation of its sediments from land masses lying both north and south or southeast of central Pennsylvania.

Juniata epoch.—During the Juniata epoch deposition of sandy and muddy sediments continued. Considerable variation in the kinds of sediment discharged into the water or in the transporting power of the currents by which the sediment was distributed is attested by the alternating beds of shale and sandstone. It is supposed that the red sediments predominating in the Juniata were derived from an area on the east upon which had accumulated a deep residual soil. This iron-stained soil was transported toward the western sea of the time, occupying a large area in Ohio, Indiana, Kentucky, and Canada, and was deposited as a great delta similar to that now forming along the lower course of the Yellow River in China.

SILURIAN PERIOD

The Tuscarora epoch was one of widespread deposition of pure quartz sand in the Appalachian province. It implies much erosion of tributary land and much sorting of material, which left a mantle of comparatively coarse sand on the low land of a wide coastal plain.

The absence of fossils in the Oswego, Juniata, and Tuscarora formations is regarded as very strong evidence that they were all terrestrial, perhaps shore, deposits, exposed to the air all or part of the time and laid down before air-breathing animals had appeared upon the earth. Similar deposits of later times contain the tracks and fossil remains of air-breathing animals.

During the Clinton epoch the region was again submerged in the sea, which at times swarmed with ostracodes and other invertebrates. The feature, however, that peculiarly distinguishes the Clinton formation is the occurrence of beds of fossil and oolitic iron ore. These beds are present along the Appalachian Valley from New York to Alabama and point to a remarkable uniformity of conditions. That the iron was deposited contemporaneously in the beds in which it occurs is the most generally accepted theory. Extensive more or less sheltered lagoons in which animals flourished may be conceived. The shells and other

skeletal parts of the animals, usually in a comminuted state such as the coquina found in Florida at the present time, accumulated in these lagoons, and as calcium carbonate precipitates iron from solution, the iron, possibly brought into the lagoons in solution as iron carbonate or iron sulphate, was precipitated and mixed with the animal debris, ultimately forming the ore beds.

Between the Clinton and McKenzie epochs there is believed to have been an unrecorded interval during which the Lockport dolomite, absent in Pennsylvania, was deposited in New York and Canada.

Pure limestone marks the beginning of the McKenzie epoch. Later argillaceous sediments predominated. Animal life flourished and ostracodes and brachiopods were very abundant.

In Wills Creek time fine sediment, at intervals calcareous, seems to have been laid down everywhere, an exception in this region being the few beds of the red sandstone and shale of the Bloomsburg member. In marked contrast with the preceding McKenzie sea, the Wills Creek sea in this region was very nearly destitute of inhabitants. The salt and gypsum deposits of the equivalent Salina formation of New York indicate a more or less isolated body of water and an arid climate with excess of evaporation. Such conditions, though perhaps less extreme, may have existed in central Pennsylvania during the epoch.

During the Tonoloway epoch the deposition of nearly pure calcareous sediment for the first time since the Trenton epoch was resumed in this region. Land was probably far distant.

DEVONIAN PERIOD

By the beginning of the Devonian period the Appalachian Gulf had contracted to a rather small basin occupied by the sea of earlier Helderberg time, supposedly connected with Atlantic waters. This sea expanded to the southwest and possibly to the northeast and after Onondaga time received a vast amount of sediment from the highlands on the east and northeast, which spread out delta-like from the head of the sea or gulf in the region of the Catskill Mountains in southeastern New York and extended southwestward into southwestern Virginia and over most of West Virginia and eastern Ohio. The Tyrone area was continuously submerged and received deposits of clay and sand during the whole of the period following the Helderberg epoch.

Helderberg epoch.—The narrow Helderberg sea of the central Appalachian region extended from New York through central Pennsylvania to southwestern Virginia and was probably surrounded by very low lands on which slight erosion was going on. Deposition of limestone prevailed and conditions were favorable to life. Many of the inhabitants of the Helderberg sea were survivors from the Silurian, and some new types were introduced.

Oriskany epoch.—The Oriskany epoch marked the beginning of a revival of the transporting power of streams. Fine sand was mixed with calcareous sediment to form the thinner siliceous limestone of the Shriver, and later coarse sand and small quartz pebbles formed the Ridgeley sandstone. The Appalachian Gulf in the Oriskany epoch

extended from Canada to Alabama far beyond the limits of the Helderberg deposition. During Shriver time conditions were less favorable to life than in the Helderberg, but in Ridgeley time again became favorable, and the sea bottom was thickly populated by shell-bearing invertebrates, especially brachiopods and gastropods.

Onondaga epoch.—In central Pennsylvania during Onondaga time fine argillaceous and calcareous sedimentation prevailed. On the north and west in New York and Ohio only limestone was laid down. The shale and limestone of this area were near-shore deposits, and the limestone on the north and northwest was deposited farther from shore in clear water. Animal life was not abundant in the Tyrone region, but in some parts of the Onondaga sea it was profuse.

Marcellus, Hamilton, Portage and Chemung epochs.—The rocks of Marcellus, Hamilton, Genesee, Portage, and Chemung formations were laid down in a more or less landlocked bay or gulf, the head of which was in southeastern New York. The clay, silt, and sand of which they are composed were apparently derived from land on the northeast and southeast, whose western shore probably extended from New York southward a long distance west of the present line of the Blue Ridge. The character of these formations indicates accumulation in shallow water, which involves a long period of slow and constant subsidence of the floor of the Appalachian Gulf in order that 7,000 or 8,000 feet of shallow-water deposits might accumulate there.

The Marcellus sea was sparsely populated except by small pteropods *(Styliolina)*, which were abundant. So was the Hamilton sea, except near the end of its existence, when bryozoans and brachiopods flourished and many other forms were common. The inhabitants of the Portage sea were peculiar diminutive pelecypods and gastropods that seem to have lived in small numbers throughout the time and some larger and still less abundant cephalopods. The Chemung fauna was more abundant and larger, brachiopods and pelecypods being the predominant forms. Some fish, earliest of the vertebrates, swam in the sea.

Catskill facies epoch.—Before the beginning of Chemung deposition —in fact, soon after the close of Hamilton time—the Catskill phase of sedimentation began in eastern New York with the deposition of the Hamilton. From this time onward the deposition of these rocks continued through Portage time. Thus it happens that the red Catskill rocks diminish in thickness from the bottom upward as they extend westward and in the Tyrone region pass upward into the highest red rocks on the Allegheny Front. The red strata here are younger than any rocks in the Catskill Mountains. The Catskill red beds are best explained as a dry delta extending from what is now the Catskill Mountains to Maryland and West Virginia; the upper one-third or so is represented near Olean, New York, and near Warren, Pennsylvania, by prevailing marine fossiliferous sediment in which are local red layers.

It may be surmised that the red sediment of the Catskill was derived from an area of rocks like red granite, or from the highly oxidized

residuum of the deeply decayed crystalline rocks of a very old eastern land surface such as exists today in parts of the Southern States. The gray shale and sandstone strata at several horizons in the Catskill facies with their marine faunas probably had a northwestern source.

CARBONIFEROUS PERIOD

In the Tyrone region sedimentation went on from the Devonian period into the Mississippian epoch of the Carboniferous, with a possible break during Kinderhook time. The distinguishing feature of the Carboniferous, especially of the Pennsylvanian epoch, was the abundant vegetable growth, which supplied the material for coal. It was a time of warm climate and extensive marshes near sea level, in which plants of different kinds grew luxuriantly and, on falling, were covered by water and so preserved from decay in the same manner as vegetal debris is preserved in the peat bogs of the present day.

In the Tyrone region the same oscillations between marine and nonmarine conditions as in the Catskill may have persisted in the first half of Pocono time at least, but nonmarine conditions were fully established in the later part of the epoch, when the Burgoon sandstone was laid down.

Mauch Chunk epoch.—After an unrecorded interval of considerable length, the deposition of the prevailingly gray Pocono was succeeded by a third extensive deposition of red beds, composing the Mauch Chunk formation. The conditions in Pennsylvania during Mauch Chunk time were unfavorable for invertebrate and plant life, for the formation contains no coal beds and shows little evidence of the presence of either plants or animals. At the same time, however, in western Pennsylvania and eastern Ohio, marine limestones and shales were being deposited upon a sea bottom thickly inhabited by marine invertebrates, whose fossil remains now crowd the Greenbrier limestone member of Pennsylvania and the Maxville limestone of Ohio. The Mauch Chunk was not represented in the Tyrone area.

After the deposition of the Mauch Chunk an unrecorded interval ensued in this region that was long enough for the deposition of 10,000 feet of rock in the Pottsville troughs of Alabama. If these beds were present in this part of Pennsylvania, they would lie between the top of the Mauch Chunk and the bottom of the Pottsville beds as described below.

Pottsville epoch.—At the beginning of Pottsville deposition a trough was deepening in eastern Pennsylvania and extending southward, bordered by land around the northern end and by land, probably high, on the southeast. From these lands the rapid streams brought in immense quantities of coarse material. This deposition of coarse material went on until 1,000 feet of strata, containing many coal beds, was laid down in the Southern Anthracite field of Pennsylvania and 10,000 feet in Alabama. While these masses of Pottsville sediments were accumulating the land from central Pennsylvania westward had been worn down nearly to sea level and then, near the close of Pottsville time, was submerged and sedimentation upon it was resumed. This sedimentation, however, is not represented in the Tyrone area.

Allegheny epoch.—Deposition continued from the Pottsville into the Allegheny epoch, which was marked by rapidly alternating conditions, and as a result shale, sandstone, limestone, and coal beds succeeded one another at short intervals. Practically all the coal in western Pennsylvania occurs in the Allegheny or in higher formations that do not now exist in this quadrangle. Deposition continued in the region, at least through Conemaugh and Monongahela time, as indicated by the presence of rocks of those epochs in Broad Top Mountain south of the quadrangle. No history of this quadrangle during Permian time, the closing period of the Paleozoic era, has been preserved, but a considerable thickness of Permian rocks (Dunkard group) was deposited in the extreme southwest corner of the State, and probably Permian rocks were deposited in this region also.

MESOZOIC AND CENOZOIC ERAS

The Paleozoic era had been one of sedimentation in the Appalachian Valley and Appalachian Plateaus, during which a great series of rock formations was built up. The Mesozoic and Cenozoic, on the contrary, were eras of deformation and erosion. Very few and fragmentary records of the events of these eras have been preserved in the Appalachian province, although evidence that vast changes occurred is plainly to be seen. To a certain extent the history of the region can be inferred from records that persist in other parts of the country.

THE APPALACHIAN UPLIFT

The Dunkard epoch brought sedimentation in the northern end of the Appalachian trough to a close, and a long series of events of a totally different kind began. So far as known, from the close of Carboniferous deposition until the present time dry land has existed in the northern end of the Appalachian province, except in the areas covered by the Triassic lakes that extended from Connecticut to North Carolina. Uplift of the sea bottom was accompanied by strong deformation, by which the originally horizontal sedimentary strata of the Appalachian Valley province were folded into high anticlines and deep synclines, and west of the Allegheny Front into the low anticlines and shallow synclines of the bituminous coal fields. This folding must have taken place in Mesozoic time because the youngest Carboniferous strata are involved in it. This profound change in the history of the region is known as the Appalachian revolution.

CYCLES OF EROSION

Ever since the elevation of the Appalachian region began the wearing away of the land has been ceaseless, and if the region should cease to rise it would in time be worn down to a plain near to sea level. A surface thus reduced is called a peneplain. Should a second uplift occur, erosion would be renewed and would proceed faster on soft rocks than on harder rocks, leaving the latter standing as ridges between valleys. The tops of these ridges would for a long time approximately coincide with the surface, now uplifted, of the old peneplain. Such

cycles of erosion may be several times repeated and leave remnants of the successive peneplained surfaces as a series of hills or ridgetops, or benches along the valley walls, or spurs projecting out from them. With these broad principles of erosion in cycles as a clue, the post-Paleozoic history of this region can be read from the land forms now existing.

Kittatinny peneplain.—It is believed that during Triassic and Jurassic times the surface of the Appalachian province was eroded, possibly more than once, to a peneplain. The first of these, if there was more than one in these periods, is called the Kittatinny peneplain, because traces of it are well preserved on the flat tops of Kittatinny Mountain in eastern Pennsylvania. The crests of Dunning and Tussey Mountains and other hard sandstone ridges in Blair County and the crest of the Allegheny Front also approximately represent the uplifted surface of this peneplain. It is believed that the Kittatinny peneplain was completed before the end of Lower Cretaceous time, for in New Jersey a remnant of what is supposed to be that peneplain extends seaward beneath deposits of Lower Cretaceous age.

Schooley peneplain.—After the uplift of the Kittatinny peneplain erosion produced a second peneplain, parts of which may be the summits at 1,500 to 1,800 feet above sea level on the eastern foothills of the Allegheny Front and possibly the conspicuous bench about 1,800 feet above sea level on the outcrop of the Oswego sandstone along the east side of Tussey and west side of Lock and Dunning Mountains, although this bench may be entirely due to the outcrop of the hard Oswego sandstone. This peneplain is correlated by some with the Schooley peneplain developed on the Schooley Mountains of northern New Jersey.

Harrisburg peneplain.—After the formation of the Schooley peneplain the region was again uplifted, erosion was renewed, and the broad, rolling area of Morrison Cove, now 1,200 to 1,400 feet above sea level, was developed. This area possibly represents the Harrisburg peneplain, well developed near Harrisburg, where its altitude is about 500 feet.

Post-Harrisburg erosion.—The Harrisburg peneplain is supposed to have been uplifted unequally, and modern stream valleys have been eroded below its surface in the latter part of Tertiary and to their present depths in Quaternary time.*

Development of drainage features.—When something is known of the history of the region since the Appalachian revolution as outlined above, it is easy to understand the origin of such gaps through the ridges as McKee Gap, Dry Gap, and the gap of the Juniata at Point View. The streams that occupy these gaps flowed on the level surface of the Kittatinny peneplain, their beds being stratigraphically and topographically above the tops of the ridges of the present day.

* Ashley believes the evidence is strong that the Schooley peneplain, if restored, would be several hundred, possibly 1,200 feet above the top of Allegheny Mountain; and that concordant hill tops and terraces at lower levels are the result of local base leveling rather than remnants of widespread younger peneplains.

During subsequent uplifts they maintained their courses and eroded their beds to lower levels, as the country rose. Thus the streams have sawed, so to speak, the gorges through the ridges.

GLACIAL EPOCH

In the Pleistocene epoch of the Quaternary period the northern and central parts of the United States were covered a number of times by great ice sheets from the Canadian highlands but these did not reach the Tyrone region, the southern margin of the ice advance in Pennsylvania being 100 miles or so to the north.

RECENT EPOCH

In the Recent epoch of the Quaternary period the final sculpturing of the region to its present topographic aspect was effected, and the Recent deposits of alluvium were laid down along the lowlands bordering the streams.

PROGRESS OF LIFE

It is probable that the terrestrial plants and animals of Mesozoic and Cenozoic times, whose existence is recorded by their remains in the rocks of those eras along the Atlantic and Gulf coasts and in the Rocky Mountains, flourished in this region also. The cycads and ferns of the Triassic and Jurassic periods doubtless clothed the surface of the land and supplied nutriment to the great reptiles (dinosaurs) and the other animals that are known from tracks and skeletal remains to have been living in the areas of Connecticut, Pennsylvania and North Carolina in Triassic time. Probably the kinds of fish characteristic of the times swam in the rivers and creeks of the region. But no vestige of this life remains, because all deposits in which any of the plants or animals could have been buried and preserved were later swept away in the general erosion of the region.

In the Cretaceous period great forests of deciduous trees must have grown in which there roamed other forms of gigantic dinosaurs than those of Triassic or Jurassic time. In this period such common kinds of trees as the oak, willow, sassafras, and tulip tree first appeared upon the earth. All traces of the Cretaceous species of these, too, have been obliterated in this region, although their remains, especially leaves, are abundant in the Cretaceous deposits of New Jersey, Maryland and Virginia, having been borne into the bordering Cretaceous seas and coastal swamps by streams and winds. In Tertiary time many strange forms of mammals, known from their remains in the Rocky Mountains, probably inhabited this region also, and in Pleistocene time extinct animals whose remains are now found in swamps, bogs and caves of Pennsylvania and Maryland were the common denizens of the land. In a cave at Smith's quarry, ½ mile west of Frankstown, Pa., were found remains of a tapir, a *Megalonyx*, two species of peccary, a bison, a mastodon, and a carnivore resembling the jaguar. In a cave near Cumberland, Maryland, there have been found, among many other species, the horse.

MINERAL RESOURCES*

IRON ORE

Brown iron ore or limonite, a hydrous oxide of iron, was mined extensively and smelted in the Tyrone quadrangle many years ago but the industry was practically abandoned in the 1870's when Lake Superior ore became available at less cost.

Small local demand for iron, superiority and cheapness of the Lake and foreign ores, the general dullness of the iron trade and high royalties (50¢ per ton) demanded by owners of the ore lands ended the industry about 1885. In the previous ten years ore mining was an insignificant industry.

Back in 1876 when the Second Geological Survey examined Blair County, some of the ore mines had been abandoned "many years ago," or had been idle "about 25 years."

In the heyday of brown-ore mining there were seven furnaces in this quadrangle. Huntingdon Furnace (1796-1870), Pennsylvania Furnace (1813-1876?), and Union Furnace (1811-1852) are names on the accompanying map. Others were at Bald Eagle, Barree (1863-188–), Mount Etna (1808-1877) and Tyrone. Forges or bloomaries were operated at Barree (1794-188–), Colerain (1805-1876?), Mount Etna (1808-1877), Tyrone (1809-188–), and on Juniata River below Petersburg (1804-188–). All these furnaces and forges have been dismantled and barely a trace remains except the slag heaps and parts of foundations.

The ores, which for over half a century were mined nearby and smelted at Pennsylvania Furnace on the Centre-Huntingdon County line, largely accounted for the high reputation of Pennsylvania iron in that day.

The iron ores in this area are residual deposits on limestones of Cambrian and Ordovician age. The ore occurs as lump and wash ore mixed with clay, sand and gravel.

Old workings have been abandoned so long that for relation to the country rock one is dependent on observations made when the mines were in operation. Descriptions and discussion of origin of the ores will be found in the Pennsylvania Second Geological Survey reports on Blair, Centre, and Huntingdon Counties. A description of their origin appears also in the U. S. G. S. Bulletin 855, Geology and Mineral Resources of the Bellefonte quadrangle, Pennsylvania.

This area was long ago so thoroughly prospected for iron ore it seems rather improbable that any extensive deposits remain undiscovered. The low-grade deposits are expensive to mine and wash and they can scarcely be expected to become valuable again until the high-grade deposits in the Lake Superior region and elsewhere are exhausted or, at least, until the grade of ore shipped from them decreases markedly in iron content. Because of the large reserves of their high-grade ores, it seems unlikely that the iron ores in this quadrangle can be in demand again until many decades have passed, if ever.

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* Compiled by R. W. Stone, Pennsylvania Topographic and Geologic Survey.

LEAD AND ZINC

The lead and zinc deposits of Blair County[18] are confined to Sinking Valley, which extends from Little Juniata River in a southwesterly direction about 10 miles between Bald Eagle and Brush Mountains, which converge to a point just east of Altoona. The limestones of the valley are of Ordovician age.

Within the limestones, lead and zinc minerals have been found in several places. Much prospecting seems to indicate that the only localities which might justify the expenditure of money and effort in the search for ore are in the two ends of the valley, where some mining has been actually carried on. The chief ore body was about 1 mile west of Birmingham Station. Others are near the end of the valley called the "Kettle," east of Altoona.

HISTORY OF MINING OPERATIONS

The first lead and zinc mines of Pennsylvania were operated in the Sinking Valley, Blair County, during the Revolutionary War. The Continental Army being in great need of lead for bullets, a party was sent to investigate some lead deposits said to be in the Wilderness near Frankstown. As a result of the examination, General Daniel Roberdeau opened and worked some shallow mines in the southern end of Sinking Valley during 1778 and 1779. Several letters from General Roberdeau and others concerning these operations are in the Pennsylvania Archives (First Series), especially in Vols. 6, 7, and 8. At one time 1,000 pounds of lead was sold to the State at $6.00 a pound in the depreciated currency of that period. It is not known when the mines closed.

The next period of active mining was in 1795, when John Musser was employed by Robert Morris to drive a drainage tunnel into the side of the hill near Birmingham to connect with a shaft previously sunk. No further information is available concerning this undertaking.

It seems there was little if any more work done until 1864, when the Keystone Zinc Company was organized and with abundant capital started operations on a large scale. Most of the work was done in the northern part of the valley west of Birmingham, but investigations by this company and others were made in a number of places in the southern part of the valley. New shafts and tunnels were driven and a large reducing plant for the manufacture of zinc oxide was built near Birmingham for the treatment of ores from this and other regions. In this attempt the principal attention was given to zinc; in the previous operations only lead was sought and the zinc minerals were regarded as worthless or as part of the gangue. After six years, during which several thousand tons of ore were mined, the company became financially involved and the plant was closed in 1870. Sporadic efforts since then to discover workable ore beds in various parts of the valley met with indifferent success. In 1875 some diamond drill boring was done in the southern part of the valley and in 1876 a small quantity of ore from another property was mined and shipped to the Bamford reduction plant near Lancaster.

[18] Platt, Franklin, Zinc and Lead Deposits of the Sinking Valley: Penn. Geol. Surv. Rept. T. pp. 247-277, 1881.

The latest known attempt to reopen the mines was in 1901, when a certain company issued a prospectus and endeavored to interest capital in the project. This is said to have been merely a stock-selling scheme

OCCURRENCE AND CHARACTER OF THE ORE

The dolomitic limestone strata of Sinking Valley form a slightly overturned anticlinal fold that extends throughout the valley with the axis pitching to the southwest. Close folding and faulting shattered the rocks near Birmingham and mineral-bearing solutions have deposited the lead and zinc ores in the crevices.

In the Birmingham region where several shafts were sunk and an adit driven 347 feet into the side of the hill only one important vein seems to have been encountered, although there were many cross veins and off-shoots. This vein seemed to parallel the strike of the enclosing limestone strata, about N.65°E., and was near the crest of the anticlinal fold. Slickensides were observed on the ore and the wall rocks, showing movement subsequent to the deposition of the ore. One drift 167 feet long followed a vein said to have averaged somewhat more than 7 feet in thickness. No statement is given as to the relative proportions of the gangue and ore minerals.

In the south end of the valley the veins cut across the strata. Many were prospected over a considerable area, but it is said that few were more than 6 inches wide, although one was found with a width of 14 inches. Again no data concerning the constitution of the veins are available.

The ore consisted primarily of sphalerite and galena with dolomite, barite, pyrite and "no inconsiderable amount of brown, highly ferruginous, argillaceous matter." In the Birmingham region the zinc ore predominated whereas the ores near the "Kettle" contained more lead; in some cases the lead content exceeded that of zinc. Smithsonite, calamine and cerussite were found in the upper levels.

Platt[19] gives the following analyses of ore from the Birmingham shafts:

Analyses of zinc ore from Birmingham, Blair County, Penna.

Silica	4.53	9.67	9.67	6.90
Carbonic acid	27.80	29.80	19.03	28.69
Oxide of cadium	1.84			
Oxide of zinc	46.95	34.50	31.10	47.50
Lime	2.48	11.08	1.17	2.17
Sulphur	.74	.12	.25	.18
Lead	5.44	.82	1.09	1.20
Iron, magnesia and water	10.22	14.01	37.69	13.36
	100.00	100.00	100.00	100.00

Another writer[20] states that "the ore of Sinking Valley, Pennsylvania, treated at the Keystone Works, contained, commonly, 6 to 8

[19] Platt, Franklin: op. cit.
[20] Williams, Charles P.: Trans. Amer. Inst. Mining Eng., vol. V, p. 425, 1877.

percent galenite and gave an oxide with 25.084 percent sulphate, 73.246 zinc oxide, and 0.574 zinc sulphate."

PRODUCTION

Platt says that more than 2,000 tons of ore were mined by the Keystone Company. This probably represents the greater part of all the ore that has been obtained from all the workings in Sinking Valley.

FUTURE PROSPECTS

The present inaccessibility of the old mines prevents forming definite conclusions concerning the nature and extent of the remaining ore bodies. When the mines were closed in 1870 the prevailing opinion seemed to be that the best of the ores were exhausted. In view of the fact that extensive prospecting had been done in many places both by diamond drilling and by sinking shafts, it does not seem probable that the district possesses much merit as a lead or zinc producer.[21]

BARITE[22]

The search for lead and zinc ore not only disclosed barite or heavy spar as a gangue mineral of the ore, but also uncovered barite on the E. Kinch farm half a mile southwest of Birmingham. The farm skirts the county road and is opposite the adit of the Keystone Zinc Company. "The vein of sulphate of baryta is on the hill to the N.W. of these openings. The heavy spar is in two thin streaks, one 6 inches wide, and the other about 3 inches wide; they are separated by 2 feet of sandy limestone dipping nearly vertically, as do also the veins of heavy spar. . . . The spar at Kinch's is quite free from all impurities."

Cellular barite found on the Col. Galbraith farm 2 miles southwest of Birmingham contained 97.08 percent barium sulphate.

These occurrences are of no commercial interest.

BUILDING STONE[23]

The Tyrone quadrangle contains an abundance of sandstone, limestone and quartzite that can be and has been used for rough building stone, that is, as rubble. Rubble is the term for rough stones of irregular shapes and sizes that have been broken from larger masses, either naturally or artificially. Naturally rubble makes a more or less rough wall in which the stones have little semblance of linear arrangement, that is, they are not in reguar parallel courses. Squared blocks of stone are called ashlar.

Early settlers, imbued with the idea of permanence in construction, used the limestone that is so abundant in the valleys and broken sandstone and quartzite from floes on the mountain side for building houses and barn foundations. A few dressed or squared the blocks for the

[21] This chapter on lead and zinc is from Miller, B. L., Lead and Zinc Ores of Pennsylvania: Penna. Topog. & Geol. Survey, Bull. M.5, pp. 13-16, 1924.

[22] Platt, Franklin, The Geology of Blair County: Pennsylvania Second Geol. Survey, Rept. T, p. 272, 1881.
McCreath, A. S., Chemical Analyses: Pennsylvania Second Geol. Survey, Rept. MM, p. 369, 1879.

[23] Stone, R. W., Building Stones of Pennsylvania: Penna. Topog. & Geol. Survey, Bull. M. 15, 316 pp., 1932.

front wall of the house and used rubble for the ends and rear wall. A house at Water Street is built this way, with dressed blocks of limestone in the front wall and the other walls of varicolored sandstone rubble.

Some of the limestones weather to a uniform gray, others that are almost too dark when fresh broken become less somber with long exposure. Some of the best appearing limestone, especially that from the lower part of the Lowville, contains considerable pyrite, which on weathering may stain the stone brown.

Farm houses and barn foundations of local limestone can be seen in the Spruce Creek Valley. The Presbyterian Church, an old mill and a farm house at Graysville, illustrate the weathering to a medium gray.

Sandstones suitable for building are variable in color and physical properties. Large blocks of float stone are so abundant on the mountains that it has not been necessary to open quarries to get stone for building purposes. The varicolored Oswego, Juniata and Tuscarora sandstones and quartzites have been used where the massive blocks strew the surface within easy access of a road. Light colored or nearly white stone, all red, and mottled or streaked stone are available. A building of either the white or red stone done in ashlar and well pointed has a pleasing appearance.

At Tyrone the gray and red tough sandstone from rock floes on Bald Eagle Mountain has been used for rubble foundations, including the National Guard Armory (1912) and the laboratory of the Wilson Chemical Company, opposite the railroad station.

GANISTER[24]

A highly siliceous sedimentary rock used for furnace linings and, mixed with clay, for making refractory brick, is called ganister. The Tuscarora (Medina) quartzite meets the requirements and is used extensively in Pennsylvania. This quartzite is the main mountain-builder in central Pennsylvania and the great sheets of slide rock along the mountain faces are familiar to all travelers through this region. These flows are particularly extensive and striking near Hollidaysburg, Mount Union, and Lewistown and in this quadrangle in the gaps at Tyrone and along the northwest slope of Tussey Mountain south of Water Street. (See Plate 9, B.)

This slide rock is derived from the breaking up of ledge rock by frost action and drifting down the mountain side. Long regarded as worthless land, the mountain slopes that are covered with quartzite have become an asset and made or increased the industrial life of adjacent communities. Rock-strewn mountain sides, which have been sold for taxes, have yielded the material for millions of silica brick.

The Tuscarora quartzite, standing at a high angle, crops out along the crest of Bald Eagle Mountain, along the crest and east side of Brush Mountain, and the top and west side of Canoe Mountain. It also comes to the surface along the crest and upper half of the east

[24] Moore, E. S., and Taylor, T. G., Silica Refractories of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. M. 3, 100 pp., 1924.

face of Tussey Mountain, including Short Mountain, and underlies the upper few hundred feet of Round Top and Leading Ridge.

Ganister is quarried on Short Mountain by the Federal Refractories Company, on Tussey Mountain northwest of Barree, by E. R. Baldridge Company, and is stripped at Goodman, 2 miles south of Water Street, by the Harbison-Walker Refractories Company. The ganister industry in this area became important about 1880.

FEDERAL REFRACTORIES COMPANY

The Federal Refractories, a subsidiary of the Stowe-Fuller Company, with head offices at Cleveland, Ohio, operate a silica brick plant at Alfarata Station, near Alexandria, Pa. The post office address of the company is Alexandria. The plant was operating nearly to capacity early in 1937.

The daily capacity of this plant in silica brick is about 40,000, 9-inch equivalent brick, with the addition of 25,000 chrome and magnesia brick per month. There are 14 silica brick kilns each 36 feet in diameter and capable of holding 80,000 brick. The rock is crushed in a Farrel jaw crusher, model B, and ground in 4 wet pans 8 feet in diameter.

The rock is quarried on the north face of Short Mountain on land leased from the State Department of Forests and Waters. Short Mountain is just north of Water Street, between two branches of Juniata River. The quarry was opened in 1904. It is about 450 feet long with a working face from 10 to 90 feet high. Drilling is done with two compressed-air drills and blasting by mud capping and snake holing. The rock consists of reddish to pure white sandstone and quartzite with thin seams of clay and shale distributed through it. At the base of the quarry there is a deep red shale, indicating that the rock is grading into the red Juniata below. Above this there are several seams of bluish shale varying in thickness from 2 inches to 2 feet. The overburden in this quarry is not more than 2 to 3 feet thick, in addition to the floe rock. The shaly material readily separates from the quartzite in quarrying, but it is necessary to discard about one-third of the rock handled. The mountain rises over 200 feet above the base of the quarry.

Another quarry was formerly operated 1,180 feet farther east and around the end of the mountain in the gap. It is 445 feet long and exposes from 1 to 50 feet of strata in the face. The strike is N.30°E and the dip 10-15° S 60°E. The rock varies from a heavy bedded, gray to white quartzite, to a reddish sandstone and there are three seams of shale from 6 inches to 2 feet thick about equally distributed throughout the face. The northern 30 feet of this quarry is in the red Juniata shale and sandstone which underlies the Tuscarora formation. The beds at the outer border of the quarry are rather sharply turned upward. This seems to be at least partly due to the drag of the beds in the large fault which runs along the foot of Tussey Mountain in this region and cuts out the front ridge of Oswego formation. There is considerable talus on the property and much of it has been stripped off. It is from 2 to 12 feet thick and averages around 3 feet. In the

lower portions of the floes there is much ferruginous rock due to the mixing of fragments of the red Juniata with the Tuscarora. Higher on the mountain the talus is purer and whiter and is of good quality. The rock is carried to the brick plant by rail around the south end of Short Mountain.

E. R. BALDRIDGE COMPANY

The Baldridge Company, with head office in Hollidaysburg, holds 500 acres near Barree. The rock is shipped for ganister, ferro-silicon and highway material, and is being tested to determine its qualifications for railroad ballast. It would seem that the harder, tougher rock which will not crumble, should be quite suitable for ballast.

The operations of this company 1 mile northwest of Barree, on the Little Juniata, are quite extensive and were active in 1937. Stripped floes here are very thick near the foot of Tussey Mountain, one of them being nearly 35 feet. They have been stripped from top to bottom of the mountain for about 1/3 mile in length and probably averaged 5 feet. The Juniata formation, which outcrops well up near the top of Tussey Mountain, contaminates the talus on the northwest side with red rock. Besides using the floes, two quarries have been worked along the strike of the beds. One is high up on, and the other near the foot of the mountain. The dip is 30° southeast. The Tuscarora formation is estimated at 300 feet thick and is made up of hard, white quartzite and sandstone with shale seams from 3 to 6 inches thick. The shaly layers carry remarkable examples of the fossil, *Arthrophycus allegheniensis*. Jointing is well developed in the quarries and much of the rock can be loosened with bars. Drilling is done with steam and hand drills and mud capping is employed a great deal in breaking blocks. The rock is crushed in a 5X Champion jaw crusher and screened in trommels of 3 sizes: (1) fines, like sand; (2) chips up to ⅝ inch; (3) ¾ inch; and (4) ballast, about egg size, or ¾ to 2½ inches.

HARBISON-WALKER REFRACTORIES COMPANY

The Harbison-Walker Refractories Company, with main offices in Pittsburgh, is a large operator and controls very large reserves of quartzite in many places besides those where active operations are now in progress. This company has several silica brick plants. The Hays plant, close to Pittsburgh, uses quartzite from the slide rock on Tussey Mountain at Goodman, 2 miles south of Water Street, and on Bald Eagle Ridge near Hannah, just north of this quadrangle in Centre County. The rock is shipped in steel cars and crushed at the plant. The stripping, or quarrying operations south of Water Street are extensive. A plane running down the mountain side from an elevation of 430 feet above the Juniata River brings the rock down to the Pennsylvania Railroad close to Goodman Station. From this plane, tracks have been run along the mountain face for thousands of feet. Another plane a short distance down stream was formerly used in stripping a large area of talus. The talus in this area is from 1 to 13 feet thick. A very large floe in the gap just below the operations mentioned, has not been worked because it seems to have in it too

many red and soft fragments from the Juniata formation, or the more impure parts of the Tuscarora. Early in 1937 daily shipments of ganister were being made from Goodman.

Analyses and tests on samples of Tuscarora quartzite.

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	Total per-cent.	Fusion point degrees C Coarser mate-rial	Fusion point degrees C Through 150 mesh.	Char-acter of deposit	Percent of deposit repre-sented
1	97.50	0.98	1.22	0.10	99.80	1,737	1,722	Ledge	75
2	97.65	0.99	1.04	0.11	99.79	1,760	1,760	Ledge	80
3	98.06	0.84	0.76	0.12	99.78	1,771	1,763	Floe	80
4	98.10	0.80	0.67	0.11	99.68	1,786	1,765	Floe	85
5	98.04	0.89	0.80	0.14	99.87	1,761	1,760	Floe	50

1. Federal Refractories Company quarry, Short Mountain. Average rock from quarries.
2. E. R. Baldridge Company quarry near Barree. From quarry 420 feet long, 2-60 feet high. Numerous clay seams.
3. Harbison-Walker Refractories Company. Stripping near Goodman Station. Large floes.
4. South side of Tussey Mountain, along north side of Diamond Valley. Large floe from 2 to 7 feet thick.
5. East side of Bald Eagle Mountain north of Tyrone Gap. Floe thin and most of rock colored by iron.

BRICK CLAY, SAND AND GRAVEL

Building brick were made at Tyrone from local clay by Fuoose Brothers, but the industry was discontinued at the end of 1934. Alluvial clay deposits at the mouths of runs entering Bald Eagle Creek might be used for common brick, and an abundance of shale on the northwest side of that creek could be mixed with the clay to make better brick and tile.

Sand and gravel in the flood plain of Bald Eagle Creek is dug locally and intermittently for building purposes. Deposits of sand and gravel occur also along Juniata River below Alfarata and on the Little Juniata below Barree.

LIMESTONE[25]

Limestone is by far the greatest mineral resource in the quadrangle. Not only do great thicknesses underlie large areas, but the stone of highest grade crops out in several localities directly on a railroad. The rocks exposed include more than 3,000 feet of limestone and about 5,000 feet of dolomite. In such great thicknesses naturally there is great variation in character and composition.

The best stone for making lime occurs in the Lowville limestone and several of the large quarries are in this formation. The Helderberg,

[25] Miller, B. L., Limestones of Pennsylvania: Penna. Topog. and Geol. Survey, Bull. M. 20, 729 pp., 1934.
Butts, Charles, and Moore, Elwood S., Geology and Mineral Resources of the Bellefonte Quadrangle, Pennsylvania: U. S. Geol. Survey Bull. 855, 1936.

Trenton, Axemann, Stonehenge and Warrior limestones may be used for agricultural lime, and the more massive beds may be used for building stone. Dolomite may be burned and the resulting lime and magnesia used on the land to good advantage, especially if the farmers discard the more sandy and clayey beds.

Operations in the Ordovician and in the Helderberg limestones will be described separately.

ORDOVICIAN LIMESTONES

The large area between Bald Eagle and Tussey Mountains, constituting most of Warriorsmark, Franklin and Spruce Creek townships, and also Sinking Valley, are underlain by Cambrian and Ordovician limestones.

The most valuable limestones of the Ordovician are the Carlim, Lowville, and Trenton formations. These limestones are, in general, low in both silica and magnesia and consequently adapted to a wider variety of uses than the underlying beds. For crushed stone and building purposes the dolomitic and siliceous beds are equally satisfactory or even better in some instances. Practically every large operation of the region is in these formations.

The anticlinal structure brings the stone of good quality at the sides of the valleys where the strata dip beneath the shales and sandstones of the ridges. The only exceptions to this rule are where the strata have been broken and displaced by faults, or where the Canoe Creek syncline (downward fold) brings the upper beds down in the center of the valley, as at Union Furnace where the upper limestone beds are present about midway of the broad limestone valley through which the stream has cut its course.

The two large active limestone operations of Huntingdon County are those of the Tyrone Lime and Stone Co. and the American Lime and Stone Co. (The Warner Co.). Both were operating in 1938.

The plant of the Tyrone Lime and Stone Co., Stover quarry, is located about 1½ miles due east of Tyrone, at the southeast base of Bald Eagle Mountain. This is a large and well equipped quarry that has been operating for a number of years. The capacity of the plant is given as 200,000 tons of crushed limestone, 20,000 tons of agricultural ground limestone, 5,000 tons of pulverized limestone filler, 10,000 tons of pulverized limestone rock dust and 20,000 tons of cupola flux. The production is naturally less except during specially favorable years.

There are 32 tracks running to the quarry face. The rock is quarried by drilling holes into the footwall against the dip and shooting out the base, permitting the upper stone to slide down. This method requires considerable secondary shooting. The stone is loaded by hand. The overburden is slight and no stripping is done.

The grinding and pulverizing plant is well equipped so that practically any requirements can be met. The manager reports that mate-

rial can be furnished in which 99 percent passes through a 325-mesh screen. Some material that is carried in the return air in the cyclone tank at the top of the mill is said to be minus 700-mesh in size. This has been mixed with the other pulverized material, but a market for this product alone is sought. Some of the screenings from the crushed rock is sold to the farmers for agricultural use without further reduction and sizing.

The strata worked belong to the Carlim, Lowville, Rodman, and part of the Trenton. The Lowville seems to be present and to be from 18 to 24 feet in thickness. The strata dip steeply to the east at angles of 75° to 80°. They are slightly overturned, as they should normally dip westward beneath the Reedsville shales.

Several small faults are observable in the quarry and the rock generally has been greatly shattered. Many of the cracks have been filled with calcite veins. A few small openings contain cave travertine (stalagmites and stalactites).

A careful survey of the ledges, numbered from west to east, was made in 1917 and is summarized in the following table. The thickness and compositions have been taken from a drawing on which the results were plotted.

Stover quarry of Tyrone Lime and Stone Co.

No. of Ledge	Thickness in feet	Percentage of SiO_2	No. of Ledge	Thickness in feet	Percentage of SiO_2	No. of Ledge	Thickness in feet	Percentage of SiO_2
1	10	9.2	18	14½	1.7	33	6	1.1
2	8½	3.4	19	5	6.85	34	7	2.3
3	10½	2.3	20	4	2.8	35	3	2.2
4	17	5.7	21	8	2.3	36	1½	5.5
5	11	3.0	21a ...	7½	3.03	37	2½	6.2
6	10	4.0	22	6½	2.55	38	4	4.0
7	12	3.7	23	5	3.4	39	8	4.6
8	10½	2.95	24	11	1.5	40	8	1.15
9	11	1.8	25	9	1.2	41	12	2.15
10	9½	1.2	26	8	2.02	42	10	2.15
11	8	3.0	27	7	12.5	43	7½	2.15
12	4½	4.1	27a ...	4	19.5	44	1½	3.4
13	7½	2.7	28	2	3.7	45	4	0.7
14	16	4.2	29	6	2.8	46	4	1.1
15	6½	4.05	30	8	6.45	47	5	11.1
16	4½	6.5	31	8	3.6			
17	10½	2.2	32	5	1.6		370 feet	

1-26 probably Lowville; 27-27a Lemont member; 28-47 Carlim below Lemont.

Average analyses of Stover quarry

	1	2
$CaCo_3$	93.09	93.84
$MgCO_3$	2.76	2.50
$Al_2O_3+Fe_2O_3$	.61	.58
SiO_2	3.54	2.98

1. Mean average for entire quarry.
2. Mean average with exception of Nos. 1, 27, 27a and 47.

At Union Furnace the American Lime and Stone Co. operates three quarries. The beds exposed in the vicinity form a syncline. Quarries

1 and 2 are working the upper strata—Rodman, Lowville, and Carlim—and quarry No. 3 is opened in the underlying Bellefonte.

Nos. 1 and 2 formerly furnished stone for lime and for flux mainly, although some interbedded strata are high in silica and valuable only for concrete or ballast. The stone averages less than 3 percent SiO_2. The lime made was used for agricultural purposes. The Bellefonte ledge is present in the quarry and, if worked by itself, would yield a chemical lime. The stone from quarry No. 3 is too impure to be satisfactory either for lime or flux and has always been worked solely for crushed stone.

In 1938 only crushed stone was being produced as the fluxing trade seems to be gone. Only Quarry No. 2 was operating at the time visited. The annual capacity of the entire plant is given as 500,000 tons of crushed stone.

These quarries were surveyed and sampled under the direction of J. I. Schlegel, general superintendent, in December, 1917, and February, 1919. The dip of the beds in quarry No. 1 is 70°W. and in quarries Nos. 2 and 3, 40-45°E. Quarrying faces range up to 175 feet high.

The following tables show the thickness and composition of the different beds:

Analyses of Ordovician limestone in American Lime and Stone Co. quarry No. 1, Union Furnace, Huntingdon County

(M. M. Morris, Jr., analyst)

	Sample Numbers									
	1	2	3	4	5	6	7	8	9	10
Ft. thick	20	28	80	15	12	13	12	42	24	54
$CaCO_3$	94.23	92.33	90.09	68.83	85.72	78.10	61.72	90.68	90.80	79.75
$MgCO_3$	2.69	1.75	1.41	5.89	3.10	9.38	28.44	4.76	4.76	5.55
SiO_2	2.54	5.16	8.00	24.24	10.48	11.90	8.80	4.06	3.90	13.20
$Al_2O_3+Fe_2O_3$	0.54	0.76	0.50	1.14	0.70	0.62	1.04	0.50	0.54	1.50

	Sample Numbers								
	11	12	13	14	15	16	17	18	19
Ft. thick	24	12	30	80	80	60	45	27	40
$CaCO_3$	81.14	66.30	70.92	93.98	96.14	91.44	90.93	81.28	86.36
$MgCO_3$	4.56	26.20	13.60	2.78	2.40	4.14	2.57	3.68	5.00
SiO_2	13.50	6.80	14.28	3.00	1.26	4.00	5.86	13.72	8.00
$Al_2O_3+Fe_2O_3$	0.80	0.70	1.28	0.24	0.20	0.42	0.64	1.32	0.64

Analyses of Ordovician limestone in American Lime and Stone Co. quarry No. 2, Union Furnace, Huntingdon County

	Sample Numbers							
	1	2	3	4	5	6	7	8
Ft. thick	30	45	50	75	30	20	28	18
$CaCO_3$	91.69	86.74	93.60	90.42	89.66	91.18	64.77	76.45
$MgCO_3$	2.37	8.38	3.60	2.78	7.82	4.92	10.33	7.81
SiO_2	5.26	4.36	2.50	6.24	2.20	3.50	23.54	14.20
$Al_2O_3+Fe_2O_3$	0.68	0.52	0.30	0.56	0.32	0.40	1.36	1.54

	Sample Numbers				
	9	10	11	12	13
Ft. thick	10	16	24	12	18
$CaCO_3$	91.70	92.45	88.26	77.47	59.05
$MgCO_3$	3.96	3.85	7.08	12.99	25.65
SiO_2	3.94	3.40	3.50	8.94	14.20
$Al_2O_3+Fe_2O_3$	0.64	0.30	1.16	0.60	1.10

Analyses of Ordovician limestone in American Lime and Stone Co. quarry No. 3, Huntingdon County

(M. M. Morris, Jr., analyst)

	1	2	3	4	5	6
Ft. thick	30	15	15	24	8	50
$CaCO_3$	51.58	53.21	54.97	54.22	50.32	54.47
$MgCO_3$	42.76	40.43	40.87	40.68	36.38	40.28
SiO_2	4.96	5.80	3.76	4.70	12.70	4.70
$Al_2O_3+Fe_2O_3$	0.70	0.56	0.40	0.40	0.60	0.55

Samples of the Bellefonte dolomite were collected just west of Water Street and analyzed by the Cambria Steel Co.

Analyses of Ordovician limestone west of Water Street

	1a	1b
$CaCO_3$	50.37 to 96.07	78.11
$MgCO_3$	1.47 to 39.41	14.51
SiO_2	1.00 to 9.70	4.30
$Al_2O_3+Fe_2O_3$	0.58 to 3.46	2.13
S	0.02 to 0.27	0.09
P	0.004 to 0.024	0.009

1. Myerly farm just west of Water Street. a. Range of 31 samples; b. Average of 31 samples. Analyzed by Cambria Steel Co.

Several abandoned small quarries elsewhere in Warriorsmark, Franklin, Spruce Creek, and Morris townships were formerly worked for agricultural lime, but in recent years some have furnished some road metal for local use. Several of these are in the vicinity of Franklinville. It is there that Historic Indian Cave is located. This rather extensive cave has been developed by solution of portions of the Upper Ordovician (Lowville) strata.

In 1925 The Spruce Creek Dolomite and Limestone Co. opened a quarry in the Nittany dolomite about ½ mile northwest of the station at Spruce Creek and in 1927 opened a second quarry about ½ mile northeast of the station. The first quarry is about 100 feet in length, about 50 feet in width and extending eastward into the hill. It was abandoned after a year or two. The second quarry is small and located rather high up on the hillside. The average strike is about N60°E. with a dip of 35°SE. This quarry was abandoned shortly.

Average analyses from quarries of Spruce Creek Dolomite and Limestone Co.

	First quarry	*Second quarry*
$CaCO_2$	51.11	51.46
$MgCO_3$	42.09	42.34
$Al_2O_3+Fe_2O_3$	1.63	1.27
SiO_2	4.29	4.13

The Pemberton quarry of the American Lime and Stone Co., ½ mile northwest of Spruce Creek, in operation in 1937, is producing crushed limestone for roads and other construction purposes. Four large trucks are used to deliver the stone to the railroad.

A limestone quarry at Warrior Ridge on the Pennsylvania Railroad, operated by a Mr. Supplee for crushed stone, was idle early in 1937.

About 2 miles east of Tyrone, on the southeast flank of Bald Eagle Mountain, there are two quarries where Lowville and Carlim limestones have been worked (Plate 6). One of these is the Tyrone Forge quarry of the American Lime and Stone Co., and the other was operated by the Pittsburgh Limestone Co. on property leased from the former company. In the former quarry the strata are slightly overturned and dip 85° to 87°SE. The quarry opening is narrow and the west face is formed by Rodman limestone that makes a sheer wall about 160 feet high (Plate 8, A). The company used the larger blocks for the manufacture of agricultural and chemical lime and sold the spalls for flux. The other quarry was worked primarily for flux. The high-grade limestone ledge (Bellefonte ledge, Lowville) so extensively quarried at the same horizon near Bellefonte can be recognized in these quarries, but it is thinner and the stone is also somewhat less pure. In 1928 the Sterling Lime and Stone Co. leased the quarry formerly worked by the Pittsburgh Limestone Co. and since that time has been producing crushed stone. About one-half of the product is sold for road work and the remainder goes to the Interstate Amiesite Co. that has erected a plant near by. A small amount has been shipped for flux. The capacity is about 400 tons per day.

An average analysis of 190,000 tons of fluxing stone shipped from Tyrone Forge in 1920 is as follows:

Analyses of limestone at Tyrone Forge

$CaCO_3$	90.48
$MgCO_3$	5.82
SiO_2	3.80
Fe_2O_3	.51
Al_2O_3	1.23
S	.130
P	1.05
Moisture	1.05

The beds in this quarry are slightly folded, but in general have a southeasterly dip of 40° to 60°.

The stone used for amiesite varies from 5/8 to 1¾ inches in size according to specifications. It is dried in a rotary dryer, elevated to mixing troughs where it is moistened with a mixture of naphtha and kerosene. The asphaltic product is then added and mixed by two revolving cylinders with attached flanges and rotating in opposite directions. After the stone fragments are thoroughly coated, a small amount of lime is shovelled in. The material is dumped through sliding doors into cars below.

At Birmingham the Cambria Steel Co. operated a quarry from 1893 to 1895 and shipped large quantities of fluxing stone. The quarry was finally abandoned because of high silica. Analyses are given below. The strata here are of Lowville and Carlim limestones intensely crushed by proximity to the Birmingham fault, plate 14.

While the Birmingham quarry was being worked for flux the weekly average analyses ran as follows:

Analyses of Birmingham limestone

	Averages	*Typical*
$CaCO_3$	85.80 to 91.03	90.40
$MgCO_3$	3.30 to 5.87	4.06
SiO_2	3.30 to 4.60	4.02
Al_2O_3	.40 to 1.88	.47
Fe_2O_3	.15 to .80	.45

The quarry was finally abandoned for flux as the stone was regarded as too poor in quality.

Additional analyses of Cambrian and Ordovician limestones from Blair County

	1a	1b	2a	2b	3	4	5
$CaCO_3$	90.389	92.115	85.80 to 91.03	90.40	53.870	48.030	94.980
$MgCO_3$	2.245	4.234	3.30 to 5.87	4.06	41.320	37.670	3.866
SiO_2	.....	.....	3.30 to 4.60	4.02	.....	.....	.....
Al_2O_3	.....	.....	0.40 to 1.88	0.47			
Fe_2O_3	1.682*	.189*	.....	.....	1.190	2.850	0.264
	.....	.....	0.15 to 0.80	0.45			0.053
S	.....	.....	.....	.....	.045	.463	0.011
P	.....	.....	.....	.....	.013	.040	0.910
Insoluble	5.880	3.620	.....	.....	2.910	10.380	

* $Al_2O_3+FeCO_3$

1. Two limestone quarries near Tyrone. a. Hard and compact; mottled with calcite; light bluish gray. b. Irregularly seamed and mottled with calcite; hard and compact; dark gray; with conchoidal fracture. (Pa. 2nd Geo. Survey, Report M M, p. 306.)

2. Birmingham quarry of Cambria Steel Co. a. Range of many weekly averages. b. Typical weekly average. Analyzed by Cambria Steel Co.

3. Keystone Zinc Co. Near Birmingham. Conglomerate-like; irregularly seamed with white crystalline carbonate of lime; color, various shades of gray and bluish gray. (M M, p. 307.)

4. Borie property. About 6 miles southwest of Birmingham. Wall rock at deep shaft. Hard, compact; minutely crystalline, bluish gray. (M M, p. 307.)

5. Mt. Etna Furnace quarry. 5 miles north of Williamsburg. Irregularly seamed with calcite; dark bluish gray, with conchoidal fracture. (M M, p. 306.)

The Blair Limestone Co., a subsidiary of Jones & Laughlin Steel Co., has five large quarries at Blairfour in the southwest part of the quadrangle. Quarries Nos. 4 and 5 were in operation in 1929, but the latter has since been abandoned. In No. 4 the working face was about 750 feet long and height of face 265 feet at highest point, and in No. 5 about 800 feet long and height of face 150 feet. The beds worked in the two quarries, which are about ½ mile apart, are practically the same. In No. 4, the southern one, the strike is N26½°E, with dip 40°SE. In No. 5 the strike is N.26½°E, dip 38½°SE.

Generalized section, Quarry No. 5, Blair Limestone Co.

	Feet
Shaly limestones, not used	
Low silica limestones (Lowville)	400
High silica limestones (Lemont)	35
Low silica limestones (Carlim)	150
High silica limestones	

The two thick bands of low silica stone are quarried for fluxing stone. The high silica material has been quarried and crushed for road and concrete purposes. The stone used for flux runs from ¾ inch to 5 inch in size. The finer material is a by-product. This is sized and the material between ¾ and ⅜ inch is used as a concrete aggregate, in curb work and small walls, and sizes smaller than ⅜ for concrete work, top dressing for water-bound macadam roads, etc. The Blairfour quarries were operating in 1937.

HELDERBERG LIMESTONES

The Helderberg (including Tonoloway) limestones crop out across the northwest and southeast corners of the quadrangle. One belt follows the east side of the valley of Bald Eagle Creek; the other is high in the hills east and south of Petersburg, and down the river from Warrior Ridge Station nearly to Huntingdon.

These limestone beds are more than 400 feet thick. There is great variation in the character of the material, as indicated by the following detailed section by Reeside. (U. S. G. S. Prof. Paper 108, pp. 205-206.)

Section at Lincoln and Fifteenth Streets, Tyrone

Concealed; scattered outcrops of dark gray and brown fissile shale; a few bands of impure limestone.

	Feet
Helderberg limestone:	
New Scotland limestone member:	
Limestone, medium bedded (1 foot), fine grained, light gray; contains chert lentils and shale laminae	4.4
Shale, weathers brown	1.4
Limestone, impure fine grained, thin bedded light gray, in courses 8 inches thick, with shale partings	2.6
Limestone, shaly weathered	.8
Limestone, massive, heavy bedded, coarse grained, crystalline, gray; much interbedded chert	4.8
	14.0
Coeymans limestone member:	
Limestone, very impure, shaly, yellowish	3.8
Limestone, somewhat weathered, light gray, coarsely crystalline; line of chert nodules (2 by 10 inches) near the top	2.0
Limestone, massive, coarsely crystalline, dark	2.5
	8.3
Keyser limestone member:	
Limestone, single bed, light gray, fine grained, impure	1.1
Limestone, very shaly, light gray	1.8
Limestone, light gray, fine grained, platy	.8
Shale, brown, weathered	2.9
Limestone, light gray, fine grained, platy	1.1
Shale, brown weathered	2.0
Limestone, impure, brownish gray, very platy; breaks into sheets ½ inch thick	4.6
Limestone, pure, fine grained, brownish gray; in two beds separated by brown shale; has conchoidal fracture	2.7
Limestone, shaly, banded, dark gray; contains carbonaceous films	1.5
Limestone, composed entirely of stromatoporoids	2.3

Limestone, shaly, yellowish gray. Scattered heads of stromatoporoids	2.0
Limestone, composed entirely of stromatoporoids; under surface very irregular	3.2
Shale, brown, weathered	.4
Limestone, composed entirely of stromatoporoids and corals; under surface irregular	5.9
Limestone, buff, fine grained, shaly	1.5
Limestone, extremely massive, composed entirely of corals, Bryozoa and stromatoporoids	9.4
Limestone, with profusion of corals and stromatoporoids	6.0
Shale	.6
Limestone, coarsely crystalline, gray	1.0
Limestone, massive, coarsely crystalline	7.7
Limestone, coarsely crystalline, gray. Scattered stromatoporoids	3.0
Limestone, coarsely crystalline, gray	3.5
Limestone, massive, coarsely crystalline	7.7
Limestone, thin bedded (1 to 6 inches), crystalline, light gray	3.5
Limestone, massive, coarse grained, light gray	5.0
Limestone, thin bedded, gray and shale	1.5
Limestone, brownish gray to buff, in single bed standing out as a ridge; coarse, crinoidal	3.9
Limestone, thin bedded, coarse, gray	.6
Shale	.4
Limestone, buff, massive, coarse grained, crystalline	3.6
Limestone, brownish gray, single bed. Fragments of fossils in surface	2.5
Limestone, thin bedded, buff; drab on fresh fracture	2.3
	88.3

Tonoloway limestone:

Limestone, massive, buff	2.0
Limestone, massive, fine grained, buff, cherty	1.4
Limestone, massive, fine grained, buff, banded	6.4
Limestone, fissile, banded, buff; drab on fresh fracture	11.7
Shale, buff, calcareous, contorted and in places apparently brecciated	7.8
Shale, weathered, brown, earthy	1.0
Limestone, massive, fine grained; weathered surface light gray, fresh fracture drab; banded; contains some thin chert lentils	6.7
Limestone, platy, banded, fine grained, light gray	2.3
Limestone, platy, laminated, fine grained, buff	.9
Limestone, buff to light brown, platy; much geodal calcite in small crystals	1.3
Limestone, fissile, light gray	2.3
Concealed; probably platy limestone	4.0
Limestone, light gray, platy, impure	1.0
Limestone, light gray in solid bed; platy fracture	3.3
Limestone, platy, fine grained, buff	4.0
Concealed; brown shale in part	15.0
Limestone, platy, buff	2.5
Shale, calcareous and fine siliceous oolite (?); weathered surface ferruginous, brown; bedding irregular	2.4
Limestone, blocky, fine grained, buff	1.3
Shale, weathered brown	2.5
Limestone, platy, fine grained, buff	2.3
Shale, calcareous, much weathered; some fine grained sandy (?) layers (siliceous oolite?) stand out	10.3
Shale, calcareous, buff to light gray	1.5
Limestone, fairly pure, fine grained, buff, blocky fracture	4.0
Limestone, buff, platy, laminated in part	6.3
Limestone, shaly, platy, yellowish; many geodal calcite masses with large fine crystals	5.0
	109.2

The Helderberg limestones in the region have been quarried in many places for lime, flux, and crushed stone for concrete and highway construction. For agricultural lime, crushed stone, and ordinary flux, a large portion of the rocks can be used, although even for these purposes some of the shaly beds must be discarded. Near the base of the Keyser formation there is a persistent bed of extremely pure massive limestone that has been quarried for chemical lime and high-grade flux.

In Bald Eagle Valley from the Centre County line to Tyrone there has been little utilization of the Helderberg limestones. In Tyrone they have been quarried, but not for many years.

The Helderberg limestones contain stone satisfactory for a variety of purposes, but because of the interbedding of different kinds of good stone as well as shaly limestones of practically no value, any one intending to use any of these limestones should make careful investigations to determine whether the kind of stone desired occurs in bands of sufficient thickness to be economically workable.

Cement materials: High calcium limestone, suitable for the manufacture of portland cement, is abundant in this quadrangle, and there is Reedsville shale near enough so that the two rocks could be used together economically. No shaly limestone of suitable composition for the manufacture of natural portland cement has been found.

There is no great consumption of portland cement in this and the surrounding region and the portland cement plants in the eastern and western ends of the State have production capacity in excess of the demand, so there is little inducement for building a cement plant in this vicinity.

CRUSHED STONE

Large quantities of limestone are crushed for various purposes as mentioned under that heading. The Water Street Trap Rock Company, Inc., has for many years operated a quarry on the Pennsylvania Railroad 0.7 mile south of Water Street in the Oswego sandstone. The quarry in 1937 is producing ballast and aggregate for concrete. Power shovels are used for loading in the quarry. Storage bins at the plant deliver directly into railroad cars.

WHITE CLAYS[26]

INTRODUCTION

The white residual clays in the Tyrone quadrangle are derived, by weathering, from feldspathic quartzites and argillaceous and cherty limestones. These rocks are either the Gatesburg formation of Upper Cambrian or Oriskany sandstone of Lower Devonian age.

The clays are pure white to light gray and are usually accompanied by less valuable stained clays of yellow, red or even black color. The clays carry much very finely divided silica which is difficult to remove by ordinary washing processes. They also carry normal coarse sand, quartzite, and chert fragments which are easily removed.

[26] Leighton, Henry, White Clay of Pennsylvania: Pennsylvania Topog. and Geol. Survey, P. R. 112, 19 pp., 1934, with minor changes by R. W. Stone and Charles Butts. For details and tests, see this report.

Microscopic examination reveals that the white clays are true kaolins made up largely of kaolinite plates ranging between .001 and .016 millimeters in size. There is also much of the characteristic kaolinite fan and "worm" shaped material which is usually about .010 by .020 millimeters.

The physical properties indicate that these white clays are generally quite plastic, but have a low green strength. Their linear air shrinkage averages around 13 percent. They reach their maximum fire shrinkage at about 1200° to 1300° C., beyond which they are overfired. They burn to colors ranging from pure white to cream or buff.

White clays are used chiefly as refractory or semi-refractory cements and linings for converters and ladles in steel mills, for whitening portland cement and, in the washed state, as a filler in the manufacture of paper. Other possible uses are in the manufacture of saggars, linoleum, rubber goods, kalsomine and other water paints and in the manufacture of white tile, brick and chinaware.

RESIDUAL CLAYS FROM THE MINES DOLOMITE [27]

The folding of the strata in the Appalachian Mountains and the subsequent erosion of the more soluble beds has left a series of flat valleys along the axes of the anticlinal folds. These valley areas are underlain by limestones, dolomites, sandstones and shales of Ordovician and Cambrian age. Silurian sandstone, the Tuscarora, forms the high mountain ridges on either side. In the center of the valleys the Mines and Gatesburg dolomites, the latter with sandstone, crop out and in them deep weathering has produced pockets of residual iron ores and of white and varicolored residual clays. These clays are formed by weathering of the beds of argillaceous quartzite and shaly limestone within the formation and therefore tend to follow the strike of such beds. They seem to be rather closely associated with pockets of iron ore and the whiter clays are often found around the margins of iron ore pockets. However, the white and colored clays are extremely irregular in their distribution and grade into white sands or one color grades into another either along the strike or across the bedding.

QUALITY OF THE MINES AND GATESBURG CLAYS

In general, it may be said that the whiter grades of the clay are plastic, burning to a cream to a lighter buff color. Their linear air shrinkage averages around 14 percent, the volume air shrinkage about 5 percent. The maximum fire shrinkage is reached between 1350°C (cone 11) and 1430°C (cone 15). They fuse between 1615°C (cone 28) and 1650° (cone 30). Their chief use is as refractory cement for laying up silica brick, for lining converters and ladles and other purposes in steel mills, and for the manufacture of saggars. As a source of white clay for china manufacture or for filling paper they have, up to date, proved somewhat disappointing as it has been impractical to wash them free from a high percentage of very fine-grained silica which many of them carry. If a successful washing process could be

[27] As a general rule, the ore and clay deposits are in the Mines dolomite and judging from the described locations of the clay pits beyond, that is probably true for the Tyrone quadrangle. Note by Charles Butts.

devised there is no doubt that the better grades could be used for these purposes.

DISTRIBUTION AND DEVELOPMENT

As shown on the geologic map the Gatesburg formation underlies a large area from the northeast corner of the quadrangle to Birmingham. Much of the area is wooded and the surface is covered with sand and quartzite fragments so that the finding of clay pockets is difficult. They have usually been found through the search in former days for iron ore. Other masses of good white clay may yet be discovered. The known deposits in this quadrangle will be described in order beginning at the north.

Furnace Road.—This pit has been known as the Kelsey ore pit, the Gates mine, and the Colonial Clay Co. mine. It is now controlled by the Everett-Saxon Company, 1710 Franklin Trust Building, Philadelphia, Penna. It is located 1 mile north of Furnace Road station on the Scotia-Tyrone branch of the Pennsylvania Railroad in Centre County, at the east side of a 1488-foot hill. In former years white clay has been excavated from large pits with steam shovels and drag line and hauled to Furnace Road for shipment. In 1927 the railroad discontinued service and no further mining was done. The Bellefonte Central Railroad now controls the branch railroad. Prospecting in the east end of the pits and drillings show 6 feet of plastic white clay above water level and 16 feet below. The old pits are now filled with water. They were last worked under lease by E. Ellenberger of Pennsylvania Furnace in a pit 75 by 400 feet. Pockets of good clay from 5 to 20 feet thick were worked. The white clay grades irregularly into white sand or into yellowish and pinkish varieties of clay. In 1922 four to seven cars of clay were shipped weekly, its use being chiefly for saggars, and as a cement in Bessemer converter linings, hot metal ladles and cupolas.

Dungarvin.—There are several old clay and ore pits near Dungarvin station on the Scotia branch of the Pennsylvania Railroad. Pits were opened some years ago under the name of J. T. Throop but in recent years they have been controlled by the Everett-Saxton Company of Philadelphia and worked under lease by William Lykens, R. D. 1, Warriorsmark. The main pits are just northwest of the station. They cover an area of 600 by 1200 feet and have an average depth of 25 feet. Exposures now show picturesque cliffs and pinnacles of every hue, and furnish a fine example of the irregular, pockety nature of these residual clays. The discontinuance of railroad service in 1927 put a stop to the working of the clay. During the war Mr. Lykens also took clay from pits south of the railroad.

Patton property.—The clay property owned by Miss Mary Patton of Hollidaysburg lies 0.7 of a mile northwest of Dungarvin and was formerly connected with the Scotia branch of the railroad by a short tram when iron ore was mined. In more recent years prospecting has been carried on for white clays by the West Virginia Pulp & Paper Company and by East Liverpool chinaware interests.

Large but irregular pockets of white clay have been encountered under a cover of 5 to 20 feet. One body of clay was 33 feet thick. The clay was said to carry 30 to 40 percent fine silica but this could be readily washed out. The companies demanded a washed product and the irregular nature of the occurrence probably worked against any large outlay of capital for such a washing plant so that the pits are now idle. Two well-constructed circular shafts 20 feet in diameter are filled with water; also an old open pit. No very good sample can now be obtained.

Pennington pit.—This pit lies ½ mile east of Eyer station or 1 mile southwest of Pennington station on the Scotia branch of the Pennsylvania Railroad. It is owned by C. J. McCauley, Second National Bank Building, Altoona, and was worked by William Lykens, R. D. 1, Warriorsmark. This operation was idle in 1936. The old loading tipple is 1000 feet east of Eyer and the pit 1000 feet southeast of the tipple. The pit shows an overburden of 10 feet of yellow soil carrying small fragments of chert and iron ore. This is underlain by from 5 to 15 feet of plastic white, gray or mottled clay. After the railroad discontinued service, the clay, dug by hand, hoisted by derrick and gas engine was trucked 2 miles to a shipping point at Stover. The clay was shipped to steel mills to be used as a cement.

Schoenberger pit.—This pit lies 2½ miles east northeast of Schoenberger and 2½ miles east of Birmingham. It is at the site of the old Dorsey iron ore pits. It is leased by Harry Eckenrode who operates it for Egan & Webster, Grant Building, Pittsburgh. The pit is 25 feet deep and shows 10 to 15 feet of white and gray clay under yellow soil, ore and chert. The clay is hoisted by a tram car on an incline, dumped into trucks, and hauled to the main line of the Pennsylvania Railroad at Schoenberger. It is shipped to steel mills for use as a refractory cement and lining.

RESIDUAL CLAYS FROM THE ORISKANY SANDSTONE

Like the Gatesburg formation the Oriskany sandstone of the Lower Devonian in places weathers into masses of white to gray clay. In central counties the Oriskany is divided into an upper zone of heavy-bedded, coarse sandstone about 100 feet thick and a lower zone of chert and shale. These are about 200 feet thick, an unusual thickness for this lower member. The clays seem to develop by weathering of the cherty portion and some of the shaly beds. The coarse upper member gives to the Oriskany a prominent outcrop forming rocky ridges and in some places where the dip is nearly vertical producing the so-called "pulpit rocks." The clay pockets should be found dipping under these coarse sandstones. Clays have been worked at two localities in the Tyrone quadrangle.

Alexandria Fire Clay Company.—This company, under the direction of G. I. Phillips, operated a white clay pit 3 miles southeast of Alexandria along the old Philadelphia Pike. It is located on a wide ridge of Oriskany sandstone known as Warrior Ridge. The pit has a high west wall of the upper Oriskany sandstone dipping steeply west;

a central zone of white clay carrying chert and some shale and dipping steeply beneath the heavy sandstone. This zone is about 50 feet wide and is minable material. The east wall consists of shale representing the lower Oriskany. It is not weathered to clay and is not used. The clay as mined is a fine-grained, white to gray, siliceous clay carrying impressions of trilobites and brachiopods, an unusual feature in residual clays. The east face of the clay zone was being worked in 1933 with a face about 30 feet wide and 30 feet high. The clay was dug with steam shovels, trucked 2 miles to the south end of Alexandria where the company has a plant equipped with rotary drier, KV hammer mill for crushing the clay, chert and shale, and large storage bins. The crushed clay is shipped to steel mills. The clay was first worked by Sam Hatfield for use in a local iron furnace; later it was shipped by way of the Pennsylvania Canal to the Barree Furnace.

Shaw[28] states that this is a siliceous clay with good burning properties; satisfactory as cement in silica brick laying but not to be used as a refractory where basic ash or slag is encountered. This operation was idle in 1936.

Petersburg.—The Alexandria Fire Clay Company owns a pit 300 feet north of Petersburg and up a steep plane. This property is no longer in use as the clay was colored. It also is weathered Oriskany material. This pit was described by Peck[29] as follows:

> The beds strike N.60°E. and dip 25°SE., and the main face of the quarry shows a thick deposit of residual clay overlain by sandstone. The clay is probably derived from the shaly limestone of the Shriver formation, the basal formation of the Oriskany group in this area, and the sandstone over it is the Ridgeley sandstone, the upper formation of the Oriskany group. A sandy shale, which also belongs to the Shriver formation, lies between the limestone and the sandstone. There is no white clay here, as at Saylorsburg, and the material is all reds or black. It is ground before shipment, but the uses are not known.

In 1936 a small deposit of white clay on the hillside southeast of Petersburg was being operated by C. R. Reeder.

CAVES[30]

Two of the twelve commercialized caves in Pennsylvania are in the Tyrone quadrangle and at least one other cave. Like most of the hundred or more caves in the State, these three are in limestone. Arch Spring cave near Tyrone and Historic Indian cave at Franklinville are in the Trenton limestone, and the Lincoln cavern on Warrior Ridge west of Huntingdon is in the Helderberg limestone.

ARCH SPRING CAVE

On a branch of Sinking Run about 5 miles south of Tyrone and 2 miles south of Union Furnace is Arch Spring, the name being derived from a limestone arch through which a stream emerges to daylight. About 1 mile southwest, at the lower end of a small rocky ravine

[28] Shaw, J. B., Fire clays of Pennsylvania: Pennsylvania Topog. & Geol. Survey, Bull. M 10, 1928.

[29] Peck, F. B., High-grade clays of the eastern United States: U. S. Geol. Survey, Bull. 708, p. 115, 1922.

[30] Stone, R. W., Pennsylvania Caves: Pennsylvania Topog. and Geol. Survey, Bull G-3, second edition, 1932. This 120-page book contains full descriptions with maps of developed caves.

beside the road, is the wedge-shaped entrance to a cave under limestone beds dipping SE about 15°. The opening is 40 feet wide and 12 feet high.

Under normal conditions one can enter for about 175 feet. It is possible that by wading one could go much farther and possibly follow the stream that enters the cave to its exit at Arch Spring.

HISTORIC INDIAN CAVE

In the bluff along Spruce Creek at Franklinville is a cave that from time beyond memory was frequented by Indians. In 1928 Mr. and Mrs. H. A. Wertz bought the land on which the cave is located and in 1929 opened Historic Indian cave to the public.

The cave is developed mostly along the bedding and parallel joints at right angles to the bedding; the pattern therefore is somewhat rectilinear and characteristic by long narrow passages. As at present developed, the route over which visitors are guided is about 1700 feet or ⅓ of a mile, including about 500 feet of retraced path. Flowstone and dripstone are abundant in this cave. The beds dip SE 40°.

LINCOLN CAVERNS

In May, 1930, when Route 22 was being relocated, blasting disclosed a cave alongside the highway. This cave was opened to the public in June, 1931 by H. W. Stewart as Hi-way-ma Caverns. In 1932 he changed the name to William Penn Caverns. In 1937 under other ownership it was advertised as Lincoln Caverns.

This is a small cave but rich in interest. Dripstone and flowstone are abundant. A cascade of flowstone of various colors and sparkling brilliance rivals the best in the State. A ponderous stalactite suspended in a natural niche over a crystal basin full of water excites admiration.

WATER RESOURCES*

By S. W. Lohman

Surface water. The Tyrone quadrangle is well watered. Juniata River, Little Juniata River, Bald Eagle and Spruce creeks are the principal streams. Spring-fed runs and creeks are numerous. The areas with least surface water are the high mountains and The Barrens.

Ground water.—Domestic supplies at the farms and most of the villages in the Tyrone quadrangle are still obtained largely from dug wells, but small springs are extensively utilized, particularly in some of the valleys that border high ridges. There are numerous drilled wells in the county, and all the wells being put down at present are of this type. A few large limestone springs issue from the Cambrian-Ordovician rocks in the large valleys, the largest of which is Hundred Springs, ½ mile northwest of Birmingham, with an aggregate

* For details, see Lohman, S. W., Ground water in south-central Pennsylvania: Pennsylvania Topog. & Geol. Survey, Bull. W 5, 1938.

yield from many openings of about 2,800 gallons a minute. All the water from this spring is pumped to Tyrone where it is used in the manufacture of paper by the West Virginia Pulp and Paper Company. This company also derives water from Bald Eagle Creek and from drilled wells.

Besides its use for domestic purposes, ground water is provided for stock, for cooling, laundries, concrete products and other industrial uses.

The Ridgeley sandstone, and to a lesser extent the sandy Shriver chert crop out over large areas on Warrior Ridge, where they are weathered to a considerable depth by the removal of their calcareous cement. The resulting blanket of loose sand and disintegrated sandstone is so permeable that water falling as rain on the ridge sinks rapidly to the less permeable parts of the Shriver and Helderberg and emerges near the foot of the ridge as springs, such as Big Spring in Tyrone which is reported to yield 4,500 gallons a minute. The water table stands far beneath the surface on most parts of the ridge, making it necessary to case off thick beds of loose material before water is reached.

Public supply. The only public supply in the quadrangle is at Tyrone where surface water from small streams along the Allegheny Front is used.

SOILS

The soils of the Tyrone quadrangle consist entirely of residual materials from the rocks of the region, and in most places, except on the mountain slopes, almost entirely from the rocks that immediately underlie the soils. There is thus a very close relation between the distribution of the soils and of the rock formations of the quadrangle. This condition is therefore in contrast to that found in glaciated areas in some parts of Pennsylvania, where most of the soil has been transported long distances by the glaciers.

The most productive soils are those derived from the limestones and dolomites, but even these require a good deal of lime, or crushed limestone, to "sweeten" the soils made "sour" when the calcareous materials have been removed in solution.

The Gatesburg formation produces a very sandy soil, which is too acid and in dry seasons too arid for agricultural use, although a few fairly good farms lie within the borders of this formation, on the interbedded dolomite strata. Owing to the poor quality of the soil in the region underlain by this formation the area is locally known as "The Barrens," and little attempt is made to farm it.

The Mines dolomite produces in many places a good soil, but most of it is acid and very stony, owing to the vast amount of chert which it contains. The same statement may be made concerning parts of the lower portion of the Nittany dolomite which carries a great deal of chert and some sandy beds. The other dolomites and limestones carry less silica.

The Reedsville shale leaves a fair soil where it is not too high in iron and not too deeply covered with sandy wash from the mountains. The soil from the Juniata is farmed, but it is dry and high in iron. Most of the farms which were taken up on this formation in the earlier days of the settlement of the region have been abandoned. The residual materials from the Hamilton and Marcellus shales and from parts of the Portage and Chemung shales make good soils. On account of its topographic position, the Chemung formation tends to wash too rapidly and to leave a surface covered with fragments of shale and fine-grained sandstone. The Catskill formation leaves fairly good soil where there is not too much sandstone and where topographic conditions are favorable. Much of its area is favorable for fruit culture.

The Oswego, Tuscarora, Pocono, Mauch Chunk, Pottsville and parts of the Oriskany, Portage, Chemung and Catskill formations have remained in forest, as they produce a poor soil. Tussey Mountain is set aside as a portion of the State forest reserve.

The area covered with alluvium along the streams, outside of the Bald Eagle Valley and on Juniata and Little Juniata Rivers near Petersburg, is comparatively small in this region. The soil is, however, of good quality.

The soils of Centre, Blair and Huntingdon Counties, in which the Tyrone quadrangle lies, have been mapped and described elsewhere.[31]

[31] Soil Survey Centre County, Pa., U. S. Dept. Agr., 1910.
Soil Survey Blair County, Pa., U. S. Dept. Agr., 1915.
Soil Survey Huntingdon County, Pa., U. S. Dept. Agr., in preparation.

LOCAL GEOGRAPHIC INDEX

A

Alexandria, 43, 45, 47, 48, 74, 94, 108, 109
Alfarata, 38, 94, 96
Allegheny Front, 5, 65, 67-70, 73, 77, 84, 86, 87, 110
Allegheny Mountain, 4
Altoona, 65, 90
Arch Spring, 7, 109
Axemann, 16

B

Baileyville, 14
Bald Eagle, 28, 65, 78
Bald Eagle Creek, 6, 47, 48, 57, 59, 60, 64-67, 96, 103, 110, 111
Bald Eagle Furnace, 89
Bald Eagle Mountain, 3, 5-7, 18, 25, 26, 30, 37, 39, 47, 48, 75, 78, 90, 93, 96, 97
Bald Eagle Valley, 5, 6, 58, 62, 64-67, 75, 105, 112
Barree, 30, 32, 33, 35, 38, 40, 42-46, 48, 89, 95, 96
Barree Furnace, 89, 109
Bellefonte, 15-18
Big Fill Run, 65
Birmingham, 10, 14, 15, 75-78, 90-92, 101, 102, 108, 110
Blairfour, 13. 102
Boalsburg, 18
Brush Mountain, 5, 25, 26, 90, 93
Buffalo Run, 75
Bunker Hill, 35

C

California Hollow, 6
Canoe Mountain, 93
Canoe Valley, 25
Carlim, 18
Castanea, 33
Colerain. 89
Cool Run School, 17
Covedale, 17

D

Diamond Valley, 96
Dix, 60, 65, 66
Dry Gap, 87
Duncansville, 67
Dungarvin, 9, 107
Dunning Mountain, 87

E

Eden Hill School, 18
Elk Run, 18, 19, 21, 22, 24
Eyer Station, 14, 108

F

Franklinville, 100, 109, 110
Frankstown, 88
Frankstown Branch, 9, 10, 16
Furnace Road, 107

G

Gallitzin, 73, 74
Gardner, 73
Gatesburg, 75
Gatesburg Ridge, 10
Gensinger Run, 78
Grafton, 48, 49
Graysville, 14, 17, 93
Grazier Mill, 8
Grazierville, 62
Goodman, 94-96

H

Hannah, 95
Harrell Station, 66
Henrietta, 8
Hollidaysburg, 34, 60
Horseshoe Curve, 71, 73
Honest Hollow, 14, 15
Howard, 39, 47
Huntingdon, 6, 59, 62, 64, 67, 74, 103, 109
Huntingdon Furnace, 8, 77, 89

I

Ironville, 19, 21, 24, 27

J

Juniata River, 5, 6, 9, 10, 14, 16, 17, 48, 53, 58-60, 62, 96, 110, 112

K

Kittanning Point, 71, 73

L

Lakemont, 36, 39, 47
Larke, 13
Leading Ridge, 5, 34, 38, 42, 77, 94
Lemont, 18, 20
Little Juniata River, 12, 30, 35, 38, 42, 44, 90, 96, 110, 112
Lock Haven, 3, 33, 46, 66
Lock Mountain, 5, 25, 31, 87
Long Mountain, 31

M

Marklesburg, 33, 34, 36
McKee Gap, 31, 87
Morrison Cove, 87
Mountain Orchard School, 71
Mount Etna, 16
Mount Etna Furnace, 89, 102

N

Near-hoof Hollow, 71
Newry, 67
Nittany Furnace, 15
Nittany Valley, 22-24

O

Oak Hall, 20
Ore Hill, 12

P

Pennsylvania Furnace, 14, 89
Petersburg, 35, 42, 44, 48, 51, 53, 58, 74, 89, 103, 109, 112
Pleasant Hill, 8, 9
Pleasant Hill Church, 8
Point View, 31, 87

R

Reedsville, 25
Roaring Spring, 20, 23
Rodman, 23
Round Top, 5, 34, 42, 94

S

Scotch Valley, 77
Shoenberger, 10-13, 16, 108
Short Mountain, 30, 31, 94-96
Sink Creek, 52
Sinking Run, 7
Sinking Valley, 75, 90-92
Spring Creek, 14
Spring Mount, 28
Spruce Creek, 7, 110
Spruce Creek village, 6, 7, 14, 17, 25, 28, 30, 74, 78, 100
State College, 18
Stover, 22
Swamp School, 58

T

Tussey Mountain, 3, 5-7, 25, 27, 30, 31, 38, 77, 87, 93-96
Tyrone, 6, 25-27, 37, 47, 52, 55, 58-61, 78, 93, 96, 97, 101-103, 105, 111
Tyrone Gap, 28, 29, 77, 96
Tyrone Forge, 101
Tyrone Furnace, 89

U

Union Furnace, 7, 18, 21, 22, 24-26, 89, 97-99

V

Vail, 64, 65
Vanscoyoc Run, 5, 71

W

Waddle, 14
Warrior Ridge, 49, 58, 60, 108, 109, 111
Warrior Ridge Station, 50, 51, 53, 55, 59, 101, 103
Warriorsmark, 9, 14, 75
Warriorsmark Creek, 9
Water Street, 6, 30, 93-95, 100, 105
Water Street Gap, 28
Williamsburg, 9, 10, 12, 13

PALEONTOLOGIC INDEX

A

Actinopteria, 67, 69
Aerograptus, 14
Aerograptus furciferus, 15
Alokistocare, 9
Ambocoelia umbonata, 64, 69, 70
Amphilichas trentonensis, 23
Anoplotheca acutiplicata, 63
Anoplotheca hemispheria, 36
Anoplotheca sulcata, 35, 36, 39
Anoplotheca hemispherica, 34
Arthrophycus, 31
  alleghensis, 33
Asaphiscus, 9
Asaphus, 15
Aspidopora newberryi, 26
Atrypa hystrix, 69
Atrypa reticularis, 35, 41, 52, 53, 54
Aulopora, 52
Aulopora? trentonensis, 23

B

Bathyurus, 17
Bathyurus superbus, 20, 22
Batrites aciculum, 67
Bellerophon calcifera, 15
Bellefontia collieana, 15
Beyrichia mesleri, 43, 45
Beyrichia moodeyi, 40, 42, 46
  veronica, 41
Blania, 9
Bolbocephalus, 17
Bollia sagittaformis, 60
  zygocornis, 60
Bollia ungula, 63
Bonnemaia rudis, 36
Brongniartia, 25
Bumastus trentonensis, 23
Bryozoa, 53, 54, 58
Buchiola, 64, 66
Buchiola retrostriata, 68
Burnettia, 12
Byssonichia radiata, 26

C

Calymene camerata, 52, 54
Calymene granulosa, 26
Calymene meeki, 26
Camarotoechia, 67
Camarotoechia andrewsi, 43, 45
Camarotoechia gigantea, 54
Camarotoechia horsfordi, 69
Camarotoechia lichfieldensis, 52
Camarotoechia neglecta, 41, 43
Carabocrinus radiatus, 23
Ceratopea, 17, 18
Ceratopsis chambersi, 26
Ceraurus pleurexanthemus, 25
Chonetes, 65
Chonetes, aurora, 66
Chonetes cornutus, 36
  coronatus, 64, 66
Chonetes hudsonica, 60
Chonetes jerseyensis, 54, 55, 58
Chonetes novascoticus, 36, 39
  vicinus, 64
Cladopora multipora, 46
Cladopora rectilineata, 52, 53, 54, 58
Cleiocrinus?, 23
Clelandia parabola, 15
Clidophorus, 26
Climacograptus typicalis, 26
Coelocaulus linearis, 17
Coelochilina aequalia, 20
Coelospira, 67
Colpouya, 26
Corals, 54
Crepicaphalus, 10
Crinoidea, 65, 66, 67, 69
Cryptodonta, 20
Cryptolithus tesselatus?, 23, 25
Cryptophragmus antiquatus, 22
Cryptozoon, 80
Cryptozoa proliferum, 12
Cryptozoa undulatum, 12
Ctenodonta, 26
Cynatonota, 26
Cyphotrypa corrugata, 55
Cyrtolites ornatus, 26

D

Daedalus archimedes, 33, 37
Dalmanella, 40
Dalmanella multisecta, 26
Dalmanella rogata, 25
Dalmanites limulurus, 35, 41
Dalmanites micrurus, 58
Diaphorostoma niagarensis, 35
Dicranograptus nicholsoni?, 26
Dictyonema, 15
Dinorthis pectinella, 25
Diparalasma, 17
Diparalasma elegantula, 17
Diplograptus foliaceus, 26
Dizygopleura brevisulcata, 40
Dizygopleura conjugata, 40
Dizygopleura symmetrica, 40, 41, 43
Douvillina cayuta, 69
  tioga, 69
Drepanella richardsoni, 28
Drepanellina clarki, 39, 40, 41, 43, 45

E

Eatonia medialis, 58
Eccyliomphalus multiseptarius, 15
Echinocoelia ambocoeliodes, 66
Echinosphaerites, 23
Elvinia, 12
Emanuella pennsylvanica, 66
Eospirifer macropleurus, 58

Eospirifer niagarensis, 39
Escharopora subrecta, 23
Eukloedenella sulcifrons, 40
Eurychilina, 20
Eurystonites, 18

F

Favosites, 52, 53
Favosites niagarensis, 46
Finckelnburgia, 14
Finckelnburgia plicata, 15
Fucoides graphica, 68
Fucoids, 67

G

Glyptorthis bellarugosa, 20
Gonioceras anceps?, 23
Grammysia elliptica, 71
Gypidula coeymanensis, 52, 58
  prognostica, 53, 54, 55

H

Hallopora sigillaroides, 26
Halysites catenulatus, 52, 54
Helicotoma tennesseensis, 20
Helicotoma uniangulata, 13
Helicotoma winonaensis, 13
Hemigyraspia, 15
Hemithecella expansa, 13
Herbertella vulgaris, 20
Hindella congregata, 50, 51
Homalonotus dekayi, 65
Homalonotus delphinocephalus, 35, 39, 41
Homalonotus trentonensis, 25
Homeospira marylandica, 40, 43, 45
Hormotoma artemesia, 17
Housia, 12
Hypothyridina venustula, 66

I

Irvingella, 12
Isochilina ottawa, 20
  seelyi, 20

K

Kingstonia, 9
Kloedenella cornuta, 40, 41, 43
Kloedenella gibberosa, 42, 43, 45
Kloedenella immatura, 40
Kloedenella intermedia, 40
Kloedenella nitida, 40, 42
Kloedenia centralis, 53
Kloedenia normalis, 40
Kloedenia ventralis, 40, 42, 43, 46
Krausella subequalis, 20
Kyammodes tricornis, 43, 45

L

Lecanospira complanata, 16
Leiopteria, 43
Leiorhyncus globuliforme, 68
Leperditia, 20, 52
Leperditia altoides, 54
Leperditia fabulites, 20
Leperditia gigantea, 54
Leperditia scalaris, 50, 51, 54, 55
Lepidodendron chemungense, 74
  corrugatum, 74
  scobiniforme, 74
Leptaena rhomboidalia, 52
Leptodesma, 69
Leptodesma umbonata, 71
Leptostrophia bipartita, 52
Leptostrophia interstrialis, 69
Leptostrophia perplana, 69
Levenea concinna, 52
Lingula, 67, 74
Lingula nickelsi, 26
Liocalymene clintoni, 36, 39
Liorhynchus limitare, 64
Liorhynchus mesacostale, 67
Loxonema, 63
Lyrodesma poststriatum, 26

M

Maclurea affinis, 17
Maclurea magna, 20
Mastigobolbina, 36, 39
Mastigobolbina arguta, 35
  modesta, 36
  lata, 36, 38
  retifera, 36
  typus, 35, 38
Megalonyx, 88
Menomonia avitas, 9
Merista typa, 53, 54, 55
Meristella praenuntia, 54, 55, 56
Metaplasia plicata, 60
Monotrypa magna, 23
Mytilarca, 74

N

Neolenus, 9
Nucleospira, 52
Nucleospira elegans, 58
Nucula bellistriata, 65

O

Octonaria cranei, 41
Octonaria stigmata, 63
Odontocephalus aegeria, 63
Oehlertella, 72
Oehlertella pleurites, 71
Ophileta compacta, 16
Ophileta levata, 15
Ophileta strigata, 17

Orbiculoidea lodiensis, 64
Orthodesma, 26
Orthoceras, 52, 71
Orthorhyncula, 26
Orthorhyncula linneyi, 26-28
Orthostrophia strophomenoides, 58

P

Paleocyclus rotuloides, 36
Paræchmina postica, 40, 41, 43
spinosa, 41
Paracardium doris, 66, 67
Pemphigaspis, 9, 10
Phacops, 66
Phacops cristata, 63
Phacops logani, 58
Phacops rana, 63
Pholidops multilamellosa, 60
Pholidops ovata, 54
Pholidops squamiformis, 40, 41
Pianodema subequata, 23
Plantae, 67, 74
Pleurotomaria capillaria, 66
Plectambonites, 26
Plectoceras undata, 23
Plectorthis fissicosta, 26
Plethobolbina, 39
Plethobolbina typicalis, 35
Prasopora simulatrix?, 23
Probeloceras lutheri, 67
Productella lachrymosa, 67-69
Protorhyncha ridleyana, 20
Psilochoncha inornata, 26
Pterinea, 71
Pterinea demissa, 26
Pterinea emacerata, 35
Pteridichnites biseriatus, 68
Pterochaneia fragilis, 67
Pteronites rostatus, 71
Pugnax pugnus, 67

R

Rachopteris, 74
Rafinesquina, 26
Rafinesquina champlainensis, 20
Rafinesquina minnesotensis, 23
Raphistoma obtusum, 15
Rensselaeria mutabilis, 53, 54, 55, 56
Rennselaeria ovoides, 62
Reticularia bicostata, 40
Rhinidictya trentonensis, 23
Rhipidomella emarginata, 52
Rhynchospira globosa, 55, 58
Rhyncotrema increbescens, 25
Rhyncotrema subtrigonale, 23
Rhytimya, 26
Riberia calcifera, 15
Riberia parva, 15
Roubidouxia umbilicata, 16

S

Saratogia, 12
Schellwinella chemungensis, 69
Schizambon pennsylvanicum, 15
Schizobolus truncatus, 66
Schizodus chemungensis, 71
Schizophoria striatula, 69
Schmidtella crassimarginata, 20
Schuchertella chemungensis, 71
Schuchertella deckerensis, 52
Schuchertella deformis, 53
Schurchertella elegans, 40, 41, 42, 43, 46
Scuchertella subplana, 38, 39, 41, 43
Scolithus, 31, 33, 34, 38
Sinuites cancellatus, 26
Sinuopea umbilicata, 13
Sowerybella, 26
Sowerybella transversalis, 36
Sphenopteris vespertina, 74
Sphenotus clavulus, 71
"Spirifer" arenosus, 62
"Spirifer" cyclopterus, 58
"Spirifer" disjunctus, 68, 69, 70, 71
"Spirifer" eriensis, 52
"Spirifer" macropleurus, 58
"Spirifer" mesacostalis, 67, 69
"Spirifer" mesastrialis, 69
'Spirifer" modestus, 54, 55
"Spirifer" mucronatus, 65, 66
"Spirifer" mucronatus posterus, 68
"Spirifer" octocostatus, 52, 54, 58
"Spirifer" perlamellosus, 58
"Spirifer" tullius, 66
"Spirifer" vanuxemi, 53, 54, 55
Stenochisma deckerensis, 52, 54, 55
lamellata, 54
Stictopora, 66
Stictoporella angularis?, 23
Streptelasma divaricans, 23
Stromatopora, 58
Strophalosia truncata, 64
Stropheodonta, 35
Stropheodonta arctimuscula, 60
Stropheodonta bypartita, 58
Stropheodonta maynardi, 69
Stropheodonta proutyi, 41, 43
Strophomena hallie, 26
Strophomena prisca, 20
Strophonella, 54
Strophonella leavenworthana, 58
Styliolina, 84
Styliolina fissurella, 64, 66, 67
Symphysurus convexus, 15

T

Taonurus, 65
Tentaculites, 40, 41
Tentaculites bellulus, 65
Tentaculites descissus, 69
Tentaculites gyracanthus, 53, 54, 55
Tetradium cellulosum, 22

Tetragraptus, 15
Tetradium cellulosum, 23
Thaleops ovatus, 23
Thilsura tricornis, 60
Thilipsurella secoclefta, 60
Thilsura confluens, 60
Trilobites, 8, 9, 12, 15, 22, 80, 81
Tropidoleptus carinatus, 65
Turritoma acrea, 17

U

Uncinulus, 53
Uncinulus stricklandi, 43

V

Vistulina postulosa, 64

W

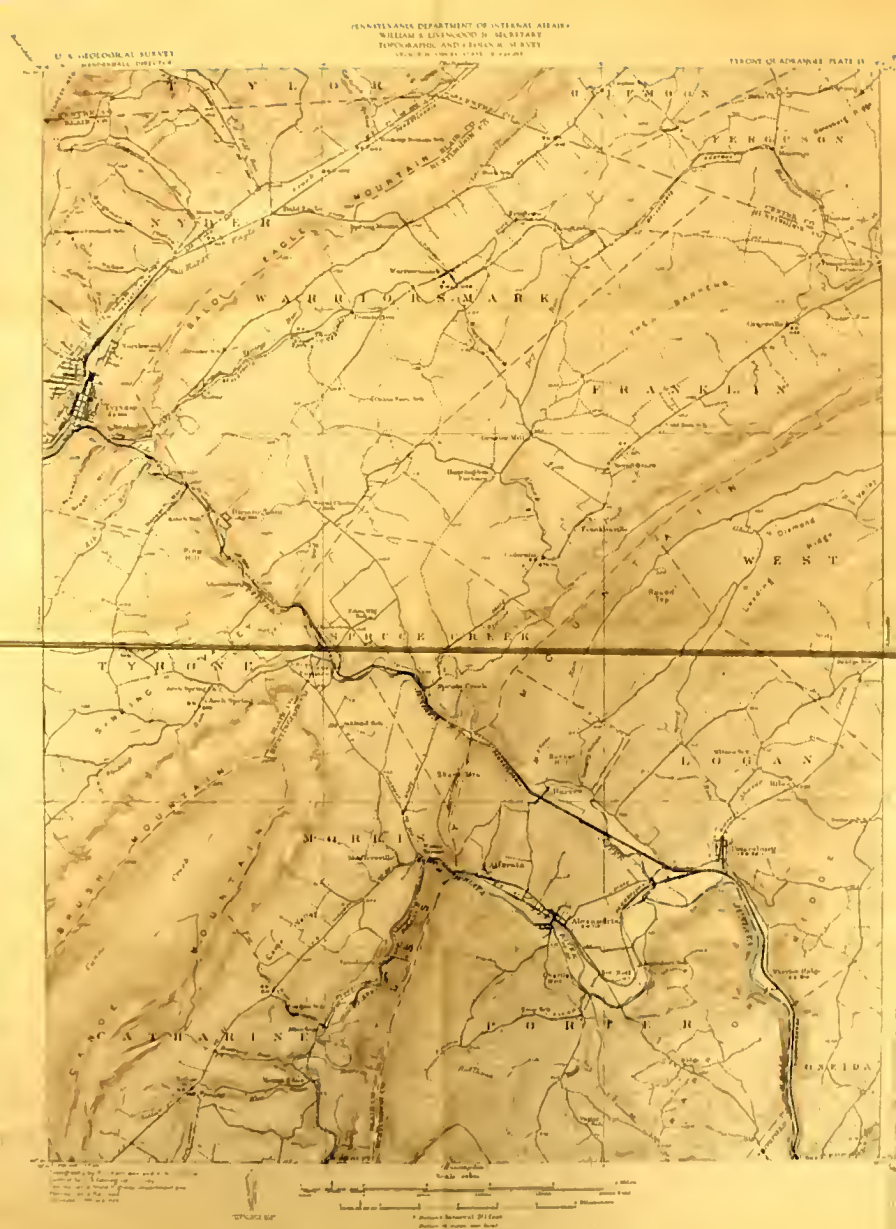
Whiteavesia, 26
Welleria obliqua, 50, 51
Whitfieldella intermedia, 35, 39, 41
Whitfieldella marylandica, 40, 41, 42, 43, 46

Z

Zygobeyrichia regina, 50
Zygobolba anticostiensis, 34, 36, 38
decora, 36, 38
erecta, 34, 36
bimuralis, 36, 38
Zygobolbina emaciata, 36, 38
Zygosella, 39
Zygosella postica, 36
Zygospira cincinnatiensis, 26

EXPLANATION

GEOLOGIC MAP OF THE TYRONE QUADRANGLE, PA



TOPOGRAPHIC MAP OF THE TYRONE QUADRANGLE, PA

GEOLOGY OF THE SOUTHERN SECTION OF THE TYRONE QUADRANGLE